55TH CONGRESS, 3d Session. | HOUSE OF REPRESENTATIVES. | DOCUMENT No. 181.

REPORT

UPON THE

FORESTRY INVESTIGATIONS

OF THE

U. S. DEPARTMENT OF AGRICULTURE.

1877-1898.

BY B. E. FERNOW,

FORMERLY CHIEF OF THE DIVISION OF FORESTRY, U. S. DEPARTMENT OF AGRICULTURE.

[PREPARED IN ACCORDANCE WITH A PROVISION IN THE ACT MAKING APPROPRIATIONS FOR THE DEPARTMENT OF AGRICULTURE FOR THE FISCAL YEAR ENDING JUNE 30, 1899.]

WASHINGTON:
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MESSAGE.

To the Senate and House of Representatives:

In accordance with a provision in the act making appropriations for the Department of Agriculture for the fiscal year ending June 30, 1899, I transmit herewith a report of the Secretary of Agriculture "upon the forestry investigations and work of the Department of Agriculture."

WILLIAM McKINLEY.

EXECUTIVE MANSION, *January 27, 1899.*

LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF THE SECRETARY,
Washington, D. C., January 24, 1899.

MR. PRESIDENT: In the act making appropriations for the Department of Agriculture for the fiscal year ending June 30, 1899, under the heading "Forestry investigations," the following provision occurs:

> *Provided*, That the Secretary of Agriculture shall make a special and detailed report at the beginning of the next session of Congress upon the forestry investigations and work of the Department of Agriculture, showing the results obtained and the practical utility of the investigations.

In accordance with the above provision, which is mandatory in its character, I herewith submit for transmission to the Congress of the United States "a special and detailed report" "upon the forestry investigations and work of the Department of Agriculture, showing the results obtained and the practical utility of the investigations."

The extremely wide scope to be covered by the report, as indicated by the language of the provision, has necessitated a voluminous report, and this fact, together with the change in the Chief of the Forestry Division, which took place July 1, 1898, will explain why the report was not presented at the beginning of the present session of Congress.

The report was necessarily prepared by the former chief, Dr. B. E. Fernow, now of the New York State College of Forestry, and I desire, in submitting it as covering the past work of the Division of Forestry of this Department, to call special attention to the fact that since the appointment of Mr. Gifford Pinchot, the present Chief, the work of the Division has been directed in distinctly different channels, which may be briefly indicated by the following summary taken from Mr. Pinchot's annual report for 1898:

> (1) To introduce in practice better methods of handling forest lands of private owners, including both wood lots and large areas chiefly held for lumber, and afterwards to spread a knowledge of what has been accomplished; (2) to assist the Western farmer to plant better trees in better ways; (3) to reduce the loss from forest fires, the reported amount of which reaches a yearly average of not less than $20,000,000; (4) and, if future appropriations will permit the necessary investigations, to inform our citizens regarding the extent and value of new opportunities for forest enterprises in Alaska, Cuba, and Puerto Rico. These objects can be pursued only so far as appropriations will permit. The present resources of the division are utterly inadequate to meet the pressing and steadily growing demands already made upon it.

These plans meet with my full approval.

I have the honor to be, Mr. President, very respectfully,

JAMES WILSON,
Secretary of Agriculture.

FORESTRY INVESTIGATIONS AND WORK OF THE DEPARTMENT OF AGRICULTURE.

REPORT BY DR. B. E. FERNOW.

New York State College of Forestry,
Cornell University,
Ithaca, N. Y., December 1, 1898.

Hon. James Wilson,
Secretary of Agriculture.

Sir: It is with great satisfaction that the writer embraces the opportunity kindly afforded by you to prepare, in answer to the inquiry of Congress, a report on the work of the Division of Forestry in the United States Department of Agriculture in the past, which is to show the resnlts and the practical utility of the investigations of the same.

Having directed the work of the Division of Forestry for more than twelve years consecutively, the writer may claim to possess intimate knowledge not only of its work, but of the aims and objects, the policy and the reasons for it, which have actuated its administration during the larger part of its existence.

If the appreciation of the public, expressed by letter and by print, can be considered as an indication of the value and utility of its work and satisfaction in the existence of the Division, it would only be necessary to inspect the files of the Division or the public prints, especially the extracts from the journals which represent the interests of forest exploitation and of the lumber trade, and are, therefore, most prominently interested in the subject for which the Division stands. While twelve years ago these publications had only ridicule and opprobrium for those who advocated the application of forestry methods in the use of our forest resources, giving them the title of "denudatics," under which the Division of Forestry was included, to-day there is no utterance of the Division which does not receive respectful hearing and full appreciation and praise in their columns, the shorter and even some of the longer publications of the Division being frequently reprinted in full.

It will, however, be more useful, as the provision of Congress calling for this report requires, to explain the work of the Division more fully. I propose, therefore, in the following pages to treat the subject in three parts: (1) Giving a brief historical sketch of the administrative features of the Division, together with the reasons for its establishment; (2) discussing the character of the work done, with the reasons for undertaking the precise kind of work which was done; (3) giving a résumé of the status of the forestry movement in the United States and the relation which the Division has had to it; placing in appendixes the more detailed facts and information of importance which the Division has collected or secured.

From this account, then, it is hoped that the value of the work of the Division, the propriety of its existence, and not only of its continuance but also of the extension of its work and functions in the future may appear. Certain it is that so far the Division has not been properly considered and endowed, and its usefulness has been impaired by insufficient appropriations and consequently limited functions.

The time has come when it should not only more vigorously pursue technical investigations, but when it should have charge of the public timber lands, and especially the public forest reservations, which will never answer their purpose until controlled by systematic management, such as all other civilized nations apply to their forest property.

HISTORICAL.

The establishment of the Division of Forestry can be traced to the action of the American Association for the Advancement of Science, which at its annual meeting at Portland in August, 1873, appointed a committee "to memorialize Congress and the several State legislatures upon the importance of promoting the cultivation of timber and the preservation of forests and to recommend proper legislation for securing these objects."

A subcommittee of this committee, consisting of Mr. George B. Emerson, a well-known educator and naturalist, and Dr. F. B. Hough, prepared the memorial [1] and furthered its consideration by the Forty-third Congress, the memorial having been transmitted to the Congress with a special message by President Grant and referred to the Committee on Public Lands in both House and Senate. Although as a result a bill was favorably reported [2] by the Committee of the House providing for the appointment of a Commissioner of Forestry, similar to the Commissioner of Fisheries, no action was taken by the Forty-third Congress, nor did the Forty-fourth Congress act on a similar bill introduced by Hon. Mark H. Dunnell, M. C. Instead an amendment was adopted to the act making appropriations for the legislative, executive, and judicial expenses of the Government for the year ending June 30, 1877, which was approved August 15, 1876, and required that the Commissioner of Agriculture "appoint a man of approved attainments and practically well acquainted with the methods of statistical inquiry, * * * with the view of ascertaining the annual amount of consumption, importation, and exportation of timber and other forest products; the probable supply for future wants, the means best adapted to the preservation and renewal of forests, the influence of forests on climate, and the measures that have been successfully applied in foreign countries or that may be deemed applicable in this country for the preservation and restoration or planting of forests, and to report upon the same to the Commissioner of Agriculture, to be by him in a separate report transmitted to Congress."

Curiously and significantly enough this clause and the appropriation of $2,000 for the purpose appears as a part of the provisions for the distribution of seeds.

In obedience to this law the then Commissioner of Agriculture, the Hon. Frederick Watts, appointed, on August 30, 1876, Dr. Franklin B. Hough, of Lowville, Lewis County, N. Y., as an agent to prepare such report, Dr. Hough not only having been most instrumental in bringing about the legislation leading to his appointment, but also being well known as a writer of local histories and gatherer of statistical material.

This appointment was continued from year to year without further special appropriation by Congress; since 1881, however, under a special appropriation as chief of an established administrative division in the Department of Agriculture.[3] Dr. Hough produced three voluminous reports, transmitted to and published by Congress in separate volumes in 1877, 1880, and 1882, and comprising in all 1,586 pages of information on a wide range of subjects.

The appropriations being extremely limited, special original research was excluded, and Dr. Hough being acquainted with the subject as an interested layman only and not as a professional forester, these reports, while valuable compilations of existing facts from various sources, naturally did not contain any original matter, except such suggestions as Dr. Hough could make with regard to the duties of the Government with reference to the forestry interests of the country and especially of the public domain.

In 1883 Dr. Hough was displaced as chief of the administrative division, although retained as an agent under the new chief, Mr. N. H. Eggleston, from Stockbridge, Mass. During Mr. Eggleston's incumbency one report was issued in 1884—the first published directly from the Department of Agriculture—comprising 462 pages. It concerned itself largely with tree-planting interests in the prairies and plains; it reported also on the decrease of woodlands in the State of Ohio and the forest conditions in some other States; it adduced statistics on the kinds and quantity of railroad ties used in the country and discussed the production of maple sugar. In a briefer report (24 pp.) embodied in the Report of the Commissioner of Agriculture for 1885 various other questions were also touched upon.

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[1] See Appendix (copy from Sen. Ex. Doc. 23, first session Forty-third Congress).

[2] Report No. 259, H. R., first session Forty third Congress.

[3] See "Readings of appropriations" further on.

On March 15, 1886, the writer assumed the position of chief of the Division of Forestry, which on July 1, by the act of Congress making provision for the expenditures of the Department for the year ending June 30, 1887, approved August 15, 1886, became a permanent statutory part of the organization of the Department.

The writer may be justified in stating here that he is a forester by profession, having received his technical education at a professional school and having been employed in the Prussian State Forestry Department. He was able, therefore, to direct the work of the Division with a professional knowledge of the requirements of the subject and from the standpoint of the forester.

His appointment having been preceded by a residence of nearly ten years in this country, he had also enjoyed ample opportunity during varied occupation in city and country, and especially as secretary of the American Forestry Association since 1883, to become acquainted with American conditions, institutions, and requirements, and to fully appreciate climatic, floral, social, and economic differences.

With gradually increased appropriations during the following years, not only was the propaganda for more rational treatment of our forest resources continued, but in addition, technical and original investigations were instituted.

With the growing interest in the subject, the correspondence with those seeking technical advice grew. As a result, besides the printed publications of the Division there are recorded in letter-press books nearly 20,000 pages of matter, largely containing specific advice given to correspondents during the twelve years of the writer's administration.

While during the years from 1876 to 1886 the aggregate of appropriations for the investigations in forestry amounted to somewhat less than $60,000, the aggregate of expenditures during the twelve years following has been, in round numbers, $230,000, excluding an appropriation of $17,000 for the artificial production of rain, which being not germane to the work of the Division and not expended under its direction, is not properly chargeable to it.

The printed information issued during this time, besides some unpublished manuscripts, comprises about 6,000 pages. It is published in four different forms, namely: annual reports contained in the reports of the Secretary of Agriculture and in the Yearbook of the Department of Agriculture; bulletins, in which more exhaustive and more or less complete investigations of any one subject are recorded; circulars of information, in which information that could be treated more briefly or preliminary announcements of results in some one line of investigation are communicated; reports to Congress, in response to calls for special information. A list of the publications of the Division is appended.

It can be claimed that at least one-half of the amount of the printed matter is original, i. e., recording results of investigations, being of an independent character and containing new truths, while for the other half originality of form or presentation of statement can at least be claimed, being compilations of facts which can not be found elsewhere in the same shape.

This means that if the money value of the manuscript pages of advice be added to that of the printed pages at a fair ratio, the information has been secured during the last period at an average price of less than $24 per page, which is hardly a fair charge for expert writing; while during the preceding period of nonprofessional writing the cost was about $30 per page. And if only the truly original information covering new additions to our knowledge is included, it has cost less than $75 per page. As to its money value to the people, which is hardly capable of expression in dollars and cents, some calculations will be found in later pages of this report when discussing the character of the work. From these it will appear that enough new information has been secured through the Division of a kind which can be translated into money through savings in useful forest materials amounting to millions of dollars and paying fifty fold for the expenditures.

The indirect value, however, in awakening an interest and proper conception of the subject, which can not be expressed in money, is infinitely greater and more important.

Appropriations, Division of Forestry, 1877 to 1897.

Year.	Salaries, statutory.	Investigation funds.	Total appropriation.	Unexpended balances.
1877			a$2,000.00	
1878			a2,500.00	
1879			a2,500.00	
1880			a2,500.00	
1881			5,000.00	$1,237.49
1882			5,000.00	.59
1883			10,000.00	1,268.01
1884			10,000.00	1.70
1885			10,000.00	12.64
1886			10,000.00	163.17
Total first period (10 years)			60,000.00	2,683.60
1887	$2,000.00	$8,000.00	10,000.00	46.50
1888	2,000.00	8,000.00	10,000.00	3.90
1889	2,000.00	8,000.00	10,000.00	.97
1890	2,000.00	8,000.00	10,000.00	.04
1891	7,820.00	b10,000.00	b17,820.00	214.01
1892	7,820.00	c15,056.85	c22,876.85	
1893	7,820.00	12,000.00	19,820.00	66.61
1894	7,820.00	c20,000.00	c27,820.00	4.04
1895	8,320.00	20,000.00	28,320.00	91.77
1896	8,520.00	25,000.00	33,520.00	6,601.88
1897	8,520.00	20,000.00	28,520.00	487.12
1898	8,520.00	20,000.00	28,520.00	275.67
Total second period (12 years)	73,160.00	174,056.85	247,216.85	

a Not especially appropriated, but disbursed from other funds for forestry investigations.
b Increase for experiments in the production of rainfall.
c Increase for investigations in timber physics, although not specially so expressed in appropriation clause until following years.

These appropriations represent not much over 1 per cent of the appropriations for the entire Department of Agriculture during the same years, a ridiculously small and disproportionate amount when the relative magnitude of the agricultural and the forestry interests are considered.

REASONS FOR CREATING A DIVISION OF FORESTRY.

The reason for establishing a Government agency where one of the largest interests in the country, the forestry interest, should find consideration and at least partial representation seems obvious if we acknowledge merely the educational function of government. This we have practically acknowledged as legitimate in the maintenance of the Department of Agriculture itself and of schools of various descriptions, experimental stations, etc. There would seem to be no need for other reasons than the fact that the absence of the art of forestry, which is practiced by other civilized nations, calls for the exercise of this educational function. But this interest has more need for governmental consideration than many others for reasons which may need fuller discussion.

They are (1) the magnitude of the manufacturing interests which rely upon the exploitation and on the continuance of the forest resources; (2) the widespread influence which forest areas, their presence or absence, and their condition have upon water flow, upon soil and climate, hence influencing navigation, damage by floods, and changes in agricultural conditions, thereby imparting to the forest cover a particular communal interest; (3) the peculiar technical and economic aspects of the art of forestry which, dealing with long time periods, does not readily recommend itself to private enterprise and needs the fostering care of the government to guard the communal interest in the forest cover.

The magnitude of the mere industrial and commercial interests which are subserved by forest growth is best expressed by a comparison with other industries, as is done in the subjoined table, from which it appears that the aggregate value of products of the industries relying for their existence on wood as raw material amounts to at least two billion dollars, second only in value to that of agricultural products. In capital and labor employed and in wages paid and value of product the forest industries and wood-manufacturing establishments outrank by far any other group of industries which may rationally be considered together. Even if the entire group of industries relying upon mineral products is considered together, it falls in value of product at least 25 per cent below that of the wood products of the country.

Leading industries compared.

[Data from Census 1890, in round numbers.]

	Capital involved.	Employees.	Wages.	Raw materials.	Products.
	Millions.	*Thousands.*	*Millions.*	*Millions.*	*Millions.*
Agriculture	15, 982	8, 286			**2,460**
Forest products, total					**1,044**
Forest industries, enumerated	562	348	102	245	446
Forest products, not enumerated (estimated)	+	+	+		598
Manufactures using wood (see table below)	543	513	294	442	907
Forest products and wood manufactures, total					**1,951**
Mineral products, total					**610**
Coal	343	300	109		160
Gold and silver	486	57	40		99
Iron and steel	414	176	96	327	479
Manufactures of iron and steel	86	60	32	79	131
Leather	102	48	25	136	178
Leather manufactures	118	186	88	153	289
Woolen manufactures	297	219	77	203	338
Cotton manufactures	354	222	70	155	268

In the following table the industries using wood in part have been classified according to an estimated per cent of wood values entering into the finished product, and a proportionate allowance has been made in capital, number, wages of employees, and raw material. Since probably more labor is employed in shaping wood than metals, the figures relating to that portion are probably under the truth.

Forest industries and manufactures using wood.

Articles.	Capital.	Employees.	Wages.	Raw material.	Value of product.
Forest industries enumerated:	*Thousands.*	*Hundreds.*	*Thousands.*	*Thousands.*	*Thousands.*
Lumber and mill products	$496, 340	2, 862	$87, 784	$231, 556	$403, 668
Timber products not manufactured at mill	61, 541	461	11, 354	11, 007	34, 290
Naval stores	4, 063	153	2, 933	3, 506	8, 077
Total	561, 943	3, 477	102, 071	245, 169	446, 034
Manufactures practically all wood:					
Cigar boxes	3, 374	55	2, 134	3, 567	7, 092
Packing boxes	13, 018	140	6, 477	14, 245	25, 513
Carriage and wagon stock	13, 028	109	5, 208	1, 388	16, 262
Carpentering	81, 543	1, 409	94, 524	137, 847	281, 195
Cooperage	17, 817	247	11, 665	2, 637	38, 618
Furniture factory products	66, 394	639	34, 471	38, 796	94, 871
Kindling wood	1, 300	18	772	1, 187	2, 402
Lasts	907	8	572	331	1, 239
Planing-mill products	120, 271	869	48, 970	104, 927	183, 682
Matches	1, 941	18	344	935	2, 194
Wood, turned and carved	7, 826	84	4, 267	3, 947	10, 940
Wooden ware	2, 712	31	1, 237	1, 499	3, 598
Wood pulp	7, 455	28	1, 229	2, 005	4, 628
Wood carpet	333	3	155	214	512
Total	337, 908	3, 650	212, 027	331, 523	672, 750
Manufactures in which wood represents about 50 per cent of the raw materials: *a*					
Total	169, 983	1, 356	714, 460	114, 383	229, 408
Wood percentage	89, 991	678	35, 730	57, 192	114, 704
Manufactures in which wood represents about 33⅓ per cent: *b*					
Total	321, 059	2, 143	123, 588	148, 578	318, 218
Wood percentage	107, 619	714	41, 196	49, 526	106, 072
Manufactures in which wood represents about 10 per cent: *c*					
Total	76, 841	915	46, 854	49, 291	131, 820
Wood percentage	7, 684	92	4, 685	4, 929	13, 182
Manufactures of wood:					
Total	543, 402	5, 134	293, 638	443, 170	906, 708

a Includes carriages and wagon factory product, children's carriages and sleds, steam and street cars, coffins and burial caskets, chairs, wheelbarrows, sewing-machine cases, artificial limbs, and refrigerators, and shipbuilding.

b Includes agricultural implements, billiard tables, railroad and street car repairs, furniture repairs, washing machines and wringers, organs and pianos.

c Includes blacksmithing and wheelwrighting, bridges, brooms and brushes, gunpowder, artist's materials, windmills, toys and games, sporting goods, lead pencils, pipes and pumps.

While these values are produced by the mere exploitation of the natural resource and their conversion into useful articles, it has been believed, predicted, and feared that, under the treatment which this resource receives at present, the natural supplies would sooner or later give out, and without attention to regrowth this large line of industries would find it difficult to secure the raw material and would thus be crippled, and hence the work of the Division was called for, in the first place, to investigate the truth of this assertion.

While by the methods and on the basis of the census it is possible to arrive at an approximate statement of the consumption, it is much more difficult to arrive at a statement of the quantity growing in the virgin forest, especially since with the reduction of supplies the method of use changes, and what was not marketable before becomes available.

The really valuable portion of the natural forest growth forms only a fraction of the whole wood growth, and the amounts of such valuable material per acre vary within exceedingly wide limits, from nothing at all to the 200,000 feet B. M. or more per acre occasionally to be found in the Pacific coast forests.

The acreage, therefore, under forest cover gives no idea of the available supplies; the condition of this cover is the important factor.

There was never at any time sufficient money appropriated to the Division to venture even on a partial investigation of this condition, except in one case, when circumstances made it possible to ascertain with tolerable precision the forest conditions of Wisconsin. Nothing less than a thoroughly organized canvass, which might cost $250,000 to $300,000, would promise any reliable, practically exhaustive information.

In the absence of such a canvass a very rough and probably very liberal estimate of the amount of the timber standing in the various regions of the country ready for the ax would give the following figures:

	Feet B. M.
Southern States	700, 000, 000, 000
Northern States	500, 000, 000, 000
Pacific coast	1, 000, 000, 000, 000
Rocky Mountains	100, 000, 000, 000
Total	2, 300, 000, 000, 000

In comparison with the supply on hand we must place the total annual cut of material requiring bolt or log size, which is estimated at about 40,000,000,000 feet B. M., more or less. That is to say, there is at best not sixty years' supply in sight, a shorter time than it takes to grow a tree suitable for milling purposes.

In this cut the various regions participate in about the following proportions:

	Feet B. M.
New England and North Atlantic States	6, 000, 000, 000
Central States	5, 000, 000, 000
Lake Region	13, 000, 000, 000
Southern States	10, 000, 000, 000
Pacific States	4, 000, 000, 000
Miscellaneous	2, 000, 000, 000

Segregating the cut by kinds, we may make the following divisions:

	Feet B. M.
White pine	12, 000, 000, 000
Spruce and fir	5, 000, 000, 000
Hemlock	4, 000, 000, 000
Longleaf pine	4, 000, 000, 000
Shortleaf and loblolly pines	3, 000, 000, 000
Cypress	500, 000, 000
Redwood	500, 000, 000
All other conifers	1, 000, 000, 000
Total conifers	30, 000, 000, 000
Oak	3, 000, 000, 000
All other hardwoods	7, 000, 000, 000
Total	40, 000, 000, 000

From this statement it appears that three-fourths of our consumption is of coniferous material. It is, therefore, of interest to know more precisely how the supply of this most important portion of our requirements stands.

In reply to a resolution of the Senate dated April 14, 1897, the writer canvassed the probabilities in this direction, at least for the Eastern States. The results are still less assuring than the above statement of total supply and consumption; for this canvass brings the available

coniferous supply in the States east of the Rocky Mountains to 400,000,000,000 feet, B. M., with which to satisfy a yearly demand of about 30,000,000,000 feet, B. M.[1]

While these figures, referring to log material, represent that portion of the forest growth which is the most valuable and has taken the longest time to grow, there is, besides the consumption for fuel, an immense amount wasted by fire, improper use, necessary and unnecessary waste.

The consumption of fuel to the extent of probably 180,000,000 cords, of fence material, etc., the waste in the woods and at the mills and loss by fire, bring the total annual wood consumption of the United States easily to 25,000,000,000 cubic feet, or since the area under wood has been ascertained to be about 500,000,000 acres, the consumption is at the rate of 50 cubic feet per acre, a figure nearly corresponding to the yield per acre realized as annual growth in the well kept forests of Prussia, where the reproduction is secured by skillful management.

The consumption, now 350 cubic feet per capita, increases from decade to decade in greater proportion than the population; and new industries, like the wood pulp industry, add constantly to the demand.

Estimates of value of forest products used in 1860, 1870, and 1880.

[Including all raw, partially manufactured, wholly manufactured wood products, fuel, and naval stores; estimated upon the basis of census figures, and other sources of information.]

Articles.	1860.	1870.	1880.	1890.
Mill products, rough, and partly finished	$155,000,000	$340,000,000	$400,000,000	$438,000,000
Cut on farms for home use	45,000,000	52,000,000	55,000,000	50,000,000
In manufactures using wood	50,000,000	100,000,000	110,000,000	150,000,000
Railroad building	6,000,000	14,000,000	30,000,000	40,000,000
Fuel	135,000,000	210,000,000	328,000,000	350,000,000
Total	[a] 391,000,000	716,000,000	923,000,000	1,028,000,000

[a] Probably 25 per cent underestimate.

This would show an increase of over 30 per cent in our consumption from decade to decade. Other statistics bearing on this phase of the subject and a fuller discussion are to be found in the Appendix.

From these statements, the compilation of which has become possible through the existence of the Division of Forestry, even if they were overdrawn to a considerable extent, it would appear that the first reason for the existence of a Government agency to look after the forestry interests is well founded.

Some ignorant people—ignorant both as to the requirements of the wood industries and as to the condition and character of our forest resources—have claimed that the natural growth of young trees, without any attention, following the operations of the lumbermen, would suffice to replace that which is removed and would continue to furnish the required material.

The observant student, not to speak of the professional forester, can readily see that culling the valuable kinds and leaving the inferior tree weeds in possession of the soil prevents in many cases any reproduction of the valuable species.

In other cases where the production of valuable kinds does take place, as, for instance, with the Southern pines, where the young growth is not killed by fires, the development is so unsatisfactory that where with proper attention a new crop might be available for the saw in seventy to one hundred years, twice the time will be required to make clear lumber of good quality. In most cases recurring fires retard this natural regrowth still further or prevent it altogether.

There is at least one State, the State of Wisconsin, for which it became practicable for the Division of Forestry to secure more accurate data as to the conditions of the forest resources and as to the results of the rough exploitation to which it is subjected in the absence of forestry methods.

This survey is published in Bulletin No. 16 of the Division. The conditions are typical of a large part of our lumbering regions, and a brief résumé will accentuate the need of attention on the part of the Government:

The State of Wisconsin, with a population of about 2,000,000, a taxable property of about $600,000,000, has a home consumption of over 600,000,000 feet B. M. of lumber, besides enormous quantities of other wood material,

[1] See Senate Doc. No. 40, first session Fifty-fifth Congress, and fuller discussion in Appendix.

which, if imported, would cost the State over $25,000,000. Of its northern half, a land surface of over 18,000,000 acres, only 7 per cent is cultivated, the rest forming one continuous body of forest and waste land. From this area there have been cut during the last sixty years more than 85,000,000,000 feet B. M. of pine lumber alone, and the annual cut during the past ten years exceeded on the average 3,000,000,000 feet per year.

The lumber industries exploiting this resource represented in 1890 one-sixth of the total taxable property in the State, paid to over 55,000 men the sum of over $15,000,000 in wages, and the value of their products was equal to more than one-third the entire output of agriculture in the State. Of the original stand of about 130,000,000,000 feet of pine about 17,000,000,000 feet are left, besides about 12,000,000,000 feet of hemlock and 16,000,000,000 feet of hard woods. The annual growth, which at present amounts to about 900,000,000 feet and of which only 250,000,000 feet is marketable pine and over 500,000,000 feet hard woods, is largely balanced by natural decay of the old, over-ripe timber. In almost every town of this region logging has been carried on and over 8,000,000 of the 17,000,000 acres are "cut-over" lands, largely burned over and waste. It would not be overstating it to say that 4,000,000 acres of these cut-over lands are for the present and must be for a long time in the future a desert, useless for any purpose. The wooded area proper is steadily being reduced by logging and to a smaller extent by clearing.

At present nothing is done either to protect or restock the denuded cut-over lands, of which fully 80 per cent are now unproductive waste land, and probably will remain so for a long time. This policy causes a continuous and ever-growing loss to the Commonwealth, amounting at present to about 800,000,000 feet per year of useful and much-needed material, besides gradually but surely driving from the State the industries which have been most conspicuous in its development, depriving a cold country of a valuable factor in its climatic conditions, and affecting detrimentally the character of the main drainage channels of the State.

The second reason for the establishment of the Division of Forestry is based on a consideration of the broad interest which attaches to the forest cover on account of its influence on waterflow, soil and climatic conditions, and is of even more moment than the question of material supplies.

In spite of the facts, which have become clear to most other civilized nations, namely, that a forest cover on the slopes of mountains prevents erosion and equalizes waterflow, reduces danger from floods, and decreases extremes in high and low water stages, in spite of these well known observations, the Government of the United States has persisted in allowing its vast public timber domain on the western mountain ranges to be destroyed by fire and otherwise, and spends millions of dollars annually in river and harbor bills to dig out the eroded farms, which have been swept into the river for lack of the protection of the soil at head waters and along shores.

Untold misery and poverty is inflicted upon the settlers in the lower valleys by this inattention. Instead of curing the evil by rational forest management, recourse is had to river improvements which can only be temporary, and are excessively expensive. Even the celebrated inaugurator of the jetty system, Captain Eads, came finally to the conclusion that the cure of the Mississippi floods was to be applied to the head waters and upper river shores rather than at the mouth of the river.

The Division has not failed to bring together all the available information, both of experience and experiment, which goes to confirm the relation of forest cover to waterflow, soil, and climate, presenting it in various reports, a final and full discussion of the subject being contained in Bulletin No. 7, Division of Forestry.

Since this relation, the influence of forests on surrounding conditions, is rightly claimed to impose upon the Government the duty to protect and preserve the forest cover on mountain slopes, a résumé of the present status of this question of forest influences is appended to this report.

The knowledge of the amelioration of climatic conditions which it is possible to secure by tree growth has induced the Federal Government to encourage the growing of groves on the forestless plains and prairies under the so-called timber culture act. If that act had been framed with more knowledge of the requirements of tree growth, in other words, if the Division of Forestry, with expert advice, had been in existence and had been called upon to frame the regulations, the law would have proved less of a failure than it has; less waste of energy and less disappointment would have been the share of the deluded settlers who were trying to satisfy the requirements of the law. It is well known that the law was abolished owing to the unsatisfactory results.

Nevertheless, tree planting in the forestless regions for the sake of ameliorating climatic conditions is and will be one of the occupations of the settlers of those regions. To assist these efforts has also been one of the objects for which the Division was established.

The third reason for the establishment of a Government agency to study and report on forestry was that this art was until that time entirely unknown in this country; even the very

word was absent from our dictionaries. While the necessity for its application for the reasons stated was believed to exist, its methods were absolutely unknown. Not only was it not practiced anywhere in this country, but where such an art was known to exist, its requirements being misunderstood, forest owners were unwilling to apply it, believing it unnecessary and unprofitable.

To enlighten these skeptics as to the methods of rational forest management and as to its desirability was to be the office of the Division of Forestry. The Division, then, was to be a bureau of information and investigation to report on all questions pertaining to the subject with a view of enlightening the people and inducing them to apply the teachings of forestry.

It was by statute limited in its functions, which were to be educational, not administrative or executive. Moreover, for most of the time, the appropriations were too scanty to permit of any very comprehensive inquiries or experiments.

The character of its functions is perhaps best learned from the wording of the acts, changing from time to time, in which Congress made appropriations for the Division.

READING OF APPROPRIATION CLAUSES FOR REPORTS ON FORESTRY AND DIVISION OF FORESTRY.

1877.—For purchase and distribution of new and valuable seeds and plants, sixty thousand dollars: *Provided*, That two thousand dollars of the above amount shall be expended by the Commissioner of Agriculture as compensation to some man of approved attainments, who is practically well acquainted with methods of statistical inquiry and who has evinced an intimate acquaintance with questions relating to the national wants in regard to timber, to prosecute investigations and inquiries with the view of ascertaining the annual amount of consumption, importation, and exportation of timber and other forest products, the probable supply for future wants, the means best adapted to their preservation and renewal, the influence of forests upon climate, and the measures that have been successfully applied in foreign countries or that may be deemed applicable in this country for the preservation and restoration or planting of forests; and to report upon the same to the Commissioner of Agriculture, to be by him in a separate report transmitted to Congress. For expense of putting up the same, for labor, bagging paper, twine, gum, and other necessary materials, five thousand dollars; in all, sixty-five thousand dollars.—(From legislative, executive, and judicial appropriation bill for fiscal year ending June 30, 1877, approved August 15, 1876. Third paragraph of section making appropriation for Department of Agriculture. First session, Forty-fourth Congress.)

1887.—For compensation of chief of Forestry Division, two thousand dollars; for the purpose of enabling the Commissioner of Agriculture to experiment and to continue an investigation and report upon the subject of forestry, and the collection and distribution of valuable economic forest-tree seeds and plants, eight thousand dollars; in all, ten thousand dollars.—(Act making appropriation for Department of Agriculture for the fiscal year ending June 30, 1887, and for other purposes, approved June 30, 1886.)

1890. Division of Forestry.—For the purpose of enabling the Secretary of Agriculture to experiment and continue an investigation and report upon the subject of forestry, and for traveling and other necessary expenses in the investigation and the collection and distribution of valuable economic forest-tree seeds and plants.

1891. Report on Forestry.—Division of Forestry: For the purpose of enabling the Secretary of Agriculture to experiment and continue an investigation and report upon the subject of forestry and for experiments in the production of rainfall, and for traveling and other necessary expenses in the investigation and the collection and distribution of valuable economic forest-tree seeds and plants.

1893. Division of Forestry.—For the purpose of enabling the Secretary of Agriculture to experiment and continue an investigation and report upon the subject of forestry, and for traveling and other necessary expenses in the investigation and the collection of valuable economic forest-tree seeds and plants.

1895. Division of Forestry.—For the purpose of enabling the Secretary of Agriculture to experiment and continue an investigation and report upon the subject of forestry and timbers, and for traveling and other necessary expenses in the investigation and the collection and distribution of valuable economic forest-tree seeds and plants.

1898. Division of Forestry.—For the purpose of enabling the Secretary of Agriculture to experiment and continue an investigation and report upon the subject of forestry and timbers, and for traveling and other necessary expenses in the investigation and collection and distribution of valuable economic forest-tree seeds and plants: *Provided*, That the Secretary of Agriculture shall make a special and detailed report at the beginning of the next session of Congress upon the forestry investigations and work of the Division of Forestry, showing the results and the practical utility of the investigations.

CHARACTER OF THE WORK OF THE DIVISION.

Having come to the conclusion that a Division of Forestry without forests, i. e., without control of forest property, even for experimental purposes, can act simply as a bureau of information and advice, the following considerations naturally occur: The object of establishing such a bureau was undoubtedly to influence a reform movement in the treatment of our forest resources, and hence the information furnished should be of such a nature as to induce the owner of timber lands and the consumer of forest products to change their ways. Undoubtedly the Government also

desired information upon which to be able to direct its action with regard to its own timber lands as well as to the forestry interests in general.

In proposing to furnish information toward these ends, three questions then occur:

(1) Who wants the information, and for what purpose?

(2) What is the nature of the information wanted?

(3) How is the information to be obtained?

In the case of inquiry by correspondents answer to these questions is at once supplied. It is only when the inauguration of original investigation is contemplated that these considerations are submitted to the discretion and judgment of the investigator. Nevertheless the thousands of letters asking for information, to which the 20,000 pages of letterpress mentioned before correspond, naturally indicate the character of the information most wanted, and admit of a classification both of inquirers and inquiries.

From the many letters of inquiry on file in the Division of Forestry it will at once appear that there are three classes seeking information:

(1) The consumers of forest products who need information which will aid them in an economical and advantageous use of the same.

(2) The producers of forest products, who, if owners of natural wood lands, need information in regard to the best methods of utilizing them most advantageously and securing reproduction, or if forest planters, in regard to the best methods of starting and cultivating a timber crop.

(3) The general public, the economist, the legislator, the Government, all desire the information which will allow them to appreciate the true position of forests and forestry in the economic life of the nation, and which is to serve also as a basis for Government action with reference to this subject and the problems connected with it.

This last class of inquirers was at first the largest, but soon, when it became known that specific and trustworthy information could be obtained, the first class, namely, the consumers of forest products, lumbermen, engineers, architects, builders, railway companies, became the more frequent, while the third class, the forest producers, remained in the minority, the tree-planting interests alone being prominent.

This was natural. The incentive to apply the art of forestry to wood lands by private individuals can only (or with rare exceptions) come from a desire to "make it pay." Whether the application of skill can be made to pay, or whether rough exploitation of the natural resource pays better, depends upon economic conditions, over which neither the owner nor the Government, nor its poor agency, the Division of Forestry, has any control. Only one condition could make the application of forestry pay, namely, the entire or partial reduction of virgin supplies. As long as the competition of virgin supplies, on the production of which no skill, no time, no money has been expended, must be feared, it remained questionable whether the application of skill, of time, and money could secure desirable financial results.

The writer, therefore, at the time when he commenced his labors, soon perceived that there was not much hope for a change of methods in the cutting of our forest areas, which would, for natural reasons, go on in the same manner until necessity forced a change.

On the other hand, it was much more likely that a more rational and economical use of the material, which the logger would continue to cut wastefully, could be brought about among wood consumers, hence instruction as to the properties and working qualities of our woods and their most satisfactory application, a knowledge of which was extremely deficient and the cause of much wastefulness, appeared to offer the most practical field of work, and the best means of securing the husbanding of our forest supplies while preparing for the application of forestry.

ECONOMY IN THE USE OF FOREST PRODUCTS.

This position, namely, that economy in the use of wood materials could be more readily secured than change in the methods of exploiting the natural supplies, gains additional support when we realize that the per capita consumption of wood in the United States, about 350 cubic feet annually, is from ten to twenty times larger than that of Germany and Great Britain. The margin, therefore, within which economy could be practiced is enormous.

The first and foremost effort of the division was therefore directed toward getting into communication with the large wood consumers.

One of the first circulars directed to railroad managers called attention to the fact that the chestnut oak, the bark of which is peeled for tanning purposes, the logs being formerly left to rot in the woods in many places, is as good for railroad ties as the white oak. There is evidence on file that this information was promptly utilized by various companies who had hitherto rejected this wood from misconception as to its value.

The first bulletin, issued within less than a year from the writer's assuming direction, presented a comprehensive discussion of the relation of railroads to forest supplies, showing the enormous consumption, exposing some mistaken notions which have led to wasteful uses, and describing in detail methods of lengthening the life of railroad ties. This bulletin undoubtedly stimulated the use of preservative processes, which are now much more generally applied by railroad companies in the construction of their roadbeds and renewal of ties.

These first relations with railroad managers as intelligent and influential wood consumers were continued by the publication of three later bulletins, in 1889, 1890, and 1894, in which, besides further economies in the use of wood for railroad ties, the question of substituting metal for such ties was fully discussed.

It may be asserted that there is no other publication in the world which discusses this important question so exhaustively and with so much technical detail.

The canvass to ascertain the extent to which metal railroad ties were used revealed the surprising fact that, instead of being a mere experiment, over 30,000 miles of metal railroad track was actually in operation in various parts of the world.

The reports of the managers of these tracks showed beyond question that with the proper pattern the metal tie was not only safer and more efficient and satisfactory in every respect, but also much more economical than the wooden tie, being not only longer lived, but also requiring less labor to keep the track in order. If this showing has not produced a corresponding response in our country toward changing to metal, it is due to the fact that wood can still be had too cheaply, and that our railroad properties are still managed in most cases as speculative properties rather than as permanent investments, hence economy in first cost of construction is more considered than permanency.

Soon, however, with the increase in price of wood as we emerge from the pioneering stage to one of a more settled policy, the information contained in these bulletins will become invaluable to railroad managers, as it will save them from unnecessary experimenting. Even now the economies suggested in the use of wood ties are beginning to be practiced more extensively. This subject is deemed to be of such importance that a brief résumé of its present status, prepared by the original investigator, Mr. E. E. Russell Tratman, C. E., is subjoined to this report.

To an even larger extent than in railroad construction wood is used in civil engineering and architecture. Wood to the value of $280,000,000, in round numbers, representing more than one-half of all the log size material used, enters into various structures.

In the use of wood for these purposes there was found to exist even greater ignorance, and consequently greater waste, than in the use for wood manufactures. Hence, as soon as appropriations could be secured from Congress, a thoroughly comprehensive investigation of our American timbers, their characteristics and properties, their strength and usefulness for various purposes, was instituted.

It was found that even our knowledge of the properties of wood in general was so deficient that an investigation into the general laws of its behavior, physically and mechanically, became necessary.

This comprehensive investigation into what has come to be known by the name of timber physics has proved to be the most important original work which the Division has undertaken.

So well does this investigation seem to have been planned, and so important does it appear to be, not only to the wood consumer, but to the forester, that a German reviewer, the well-known author in forestry literature, Dr. Schwappach, himself a recognized authority in forestry matters, and specially engaged in similar investigations, used the following language regarding it, as quoted in the report of the Secretary of Agriculture for 1893, page 32:

> This plan of work is as remarkable for its scope as for its consistent pursuit of an eminently practical result. Although Germany has accomplished a great deal in some directions in this field of investigation, especially as regards the laws of growth and wood structure, we are yet far from having such a comprehensive and indispensable knowl-

edge even of our most important timbers as is needful. We must admit, with a certain sense of humiliation, that the Americans show us what we really ought to know and that they have already by far surpassed us in the elaborate organization for these investigations.

And the Secretary himself adds: "If in less than a decade Americans have in a forestry specialty surpassed Germany, why can not we a generation hence rejoice in the most efficient forestry system of the world?"

If any words of interest and appreciation of this work from home sources are wanted, they can be found in the technical journals of the lumber trade, of engineering, of architecture, of carriage building, and of all branches of wood working, as well as in the large number of letters on file in the Division, the gist of a few of which are printed in Bulletin 6, and, furthermore, in a series of resolutions passed by various societies of engineers and architects and other bodies, addressed to the Secretary of Agriculture and to Congress, asking for a continuance of and better support for this work. Nevertheless, in 1896, in spite of the protestations of the writer, this line of work was ordered discontinued as "not germane to the subject of the Division."

It should not be overlooked that the increase in the appropriations for the Division, which dates from the year 1892, was made specifically for this investigation, and was continued impliedly for the same purpose.

While the full value of such extended investigation is only apparent after being long continued, and when the bearing of all data and facts collected can be fully recognized, the following tangible results, immediately applicable in actual practice, can be pointed out as testifying to the value of the work for which it was instituted, namely, the more economical use of our forest resources.

The publication of the results of the first investigation brought about the removal of the long-standing prejudice against the value of timber of Longleaf pine, which had been bled or tapped for turpentine. Hitherto specifications by architects and engineers were usually made so as to exclude bled timber, and although in general such specifications were ignored by those who furnished the material, some of the largest consumers, such as the railway companies of the South, effectively discriminated against such material, and much litigation and disappointment was the result.

By bringing out the truth in the matter not only was the industry of turpentine production exonerated from the charge of bad economy, but a value, which has been variously figured at from $2,000,000 to $4,000,000 annually, was added to the Southern pineries by the assurance that the bled material could be safely used.

The Division of Forestry was the first to establish reliable values as to the strength of our most important lumber trees for the use of engineers, who hitherto had to rely upon very doubtful values derived from unsatisfactory tests made on European species, or else on a few insufficient tests of our own species.

So great was the confidence in the methods pursued by the Division that its results were immediately embodied into the standard manuals of engineering, as, for instance, in Trautwine's Engineering Pocketbook, the companion and reference book of every American engineer.

The fact that Longleaf pine is from 20 to 25 per cent stronger than heretofore believed, renders it possible, to effect a saving of fully $6,000,000 worth of this wood per annum if applied to all of this material used. A similar factor of economy might have been established for other woods which have been investigated. The fact established by the Division, that seasoned material is stronger by 50 to 75 per cent than fresh timber, added a very considerable opportunity for saving in the design and specifications of structures under cover.

"The capital invested in timber structures is greatly in excess, probably more than two or three times as much as that invested in structures of iron and steel. Every piece in these latter structures is thoroughly inspected, both chemically and physically, and is carefully designed to carry the imposed load. Timber structures, on the other hand, have been designed according to the general principle that the Lord takes care of His own, as the great number of fatalities resulting from failure of these structures will attest." By furnishing reliable test data, based on a large series of tests, not only economy in the use of our forest resources, but a saving of life and property, could be effected. By furnishing the necessary data, now largely absent, upon which to base the inspection and specifications for wood material, the factor of safety could be placed on a proper basis. These objects have been in view in this series of investigations.

Finally the important discovery of the relation between the strength in compression and in cross breaking, the crowning result of this short-lived investigation, is of vast importance, and will not only put the designing of beams upon a surer footing, but save much useless wood testing in the future. Whether this work be considered germane to a division of forestry or not, its results will be held by future engineers and wood consumers, as well as foresters, as sufficient testimony of the usefulness of the division.

Since these investigations are now probably brought to an end as far as Government agency is concerned, it has been thought desirable to give a fuller résumé of their results in the appendix, which has been prepared by Prof. Filibert Roth, who was finally in special charge of the investigations.

I may only add that Bulletin No. 10, Timber, a Discussion of the Characteristics and Properties of Wood, prepared by Mr. Roth, which has been translated into French, is the only publication containing this kind of information, with special reference to our American woods.

Besides these more general considerations of the requirements of wood consumption, other more special classes also received attention, as the wood pulp, the naval store, the mining industry, and the charcoal iron industry. Two reports, still in manuscript, designed to assist operators in these last two lines, are to be published soon.

While then the information furnished to the wood consumer to induce a more economical use of material was most decidedly of a very useful order, the needs of the forest producer were by no means neglected.

SILVICULTURE AND FOREST ECONOMY.

Forestry, the art of wood production, may be divided into two parts, which can be treated more or less independently, namely, silviculture, which comprises all the detailed instructions that are necessary to create and grow the wood crop to perfection, and to reproduce it; and forest economy, which comprises the business methods that must be employed to manage the crop so as to yield regular annual returns; the one branch being concerned with the production of the material, the other with the production of a revenue.

Again in both cases we may distinguish between general principles and specific application. The first, fortunately for us, are already for the most part developed through the experiences of the Germans and other nations, and it is only necessary to present these general principles, when a study of local conditions, the soil, the climate, the market conditions, the species we have to deal with, etc., will enable the student of nature and the business man to form a judgment as to their applicability in his particular case.

These general principles underlying silviculture and forest economy have been again and again discussed in reports, bulletins, circulars, and public addresses by the writer. The first brief presentation of the same is to be found in the annual report of the division for 1886. A bulletin (No. 5) entitled, What is Forestry, published in an issue of 40,000 copies, was devoted to an elucidation of the same subject.

In order to bring this discussion closer to the conditions of one class of forest owners, our farmers, these silvicultural principles and methods were more fully discussed with reference to their possible application in a Farmers' Bulletin (No. 67) entitled Forestry for Farmers, while special phases of silviculture, as, for instance, the Growing of Seedlings in Nurseries, Planting of Waste Places on the Farm, Tree Planting in the Plains, Osier Culture, The Introduction of Certain Foreign Trees, etc., were discussed in separate circulars and special articles or bulletins. A discussion of the general aspects of silviculture will be found in the appendix.

The principles of forest economy were also elucidated in the various annual reports, and especially in the report for 1893, in which a statement of the methods of administration and forest regulation of the German forest departments is given in full. In addition, more complete statements of the financial results of these German forest administrations prepared in the Division were published in public prints, to show the elements of profitable forest management as exhibited by these examples.

Since these statements are scattered through various publications and are not now readily accessible, it has been deemed expedient to present the same as an appendix to this report, and thereby aid in elucidating the means which the Division has employed to make the practical appli-

cation of such forest management acceptable. A discussion of the principles of forest economy in general is also appended.

To have established the conception that forestry, silviculture, and forest preservation is not the planting of trees, but cutting them in such a manner that planting becomes unnecessary, is one of the most potent results of the efforts of the Division of Forestry. Timber-land owners have begun to realize that forestry begins when the first tree is cut. Planting is expensive and should be practiced only where the chances for a natural reproduction by intelligent use of the ax have been frustrated by man's carelessness or where they did not exist, as in the forestless regions of the West.

Forest preservation, it must by this time have become clear, does not consist in leaving the forest unused, but in securing its reproduction, just as the human race is preserved by the removal of the old and the fostering of the young.

APPLICATION OF FORESTRY PRINCIPLES.

To apply forestry principles, be it in forest economy or be it in silviculture, we must study local conditions in the field.

In this direction the Division has had, at first, poor opportunities. Not only did it not have at its command any land or forest area for experimental or demonstration purposes, but the men to carry on such field work were as yet not educated for the special work to be undertaken.

Again, while the basis for an application of forestry principles may be gained by studies in the field, the final application can be secured only by trained men, just as any other technical business requires technical knowledge and skill.

It might have been possible to make some practical demonstration of the methods of forest regulation and of silviculture by inducing private timber-land owners to permit their properties to be placed at the disposal of the Division for such demonstration, but the writer was at once met with the objection that such a course would not be a proper policy for the Government, as the use of public money for the benefit of private individuals would not be justified, even though a valuable object lesson might be gained thereby. Attempts were made to secure permission to use public timber lands or military reservations for such demonstration purposes, but without success. Practical experiments in the field were therefore excluded, with the exception of the experimental planting which became possible later through the cooperation of the agricultural State experiment stations.

The Division was on the whole reduced to such studies and investigations as could be carried on without the control of any demonstration areas. The vast extent of our empire, with such diversity of soils, climate, and economical conditions, made the task of selecting even these problems of local application an appalling one, especially under the limitations imposed by small appropriations and the absence of trained men. The large number of valuable species of trees of which the United States can boast adds to the difficulties in securing the necessary information for the application of their management in the regulated forest.

While the European forester can concentrate his attention upon a half dozen or so of the 20 or 30 species indigenous to his world, we are called upon to select from 500 species the 100 or more which we recognize as valuable for the forest. Not even their names are sufficiently established to allow a sure distinction by name among those who speak of them or handle their lumber, or are called upon to supply seeds or plants.

It was therefore a proper piece of foundation work, performed by the competent dendrologist of the Division, Mr. George B. Sudworth, to establish a nomenclature of our arborescent flora, both of vernacular and botanical names, which might form the basis of uniform usage. This excellent, painstaking, and laborious work, analyzing the propriety and identity of over 6,000 names applied to our 500 species, has been published as Bulletin 14 of the Division, followed by a more condensed list for general use as Bulletin 18.

In addition, a select list of those species which we may for the present consider of immediate economic value, with notes of their distribution, their uses, and their general silvicultural requirements, was also prepared and is reproduced in the appendix, giving an idea of the vast field open for the student of forest biology.

FOREST BIOLOGY.

In order to apply silviculture, to manage a forest crop intelligently, we must first be acquainted with the biology, the life history, and development of the different species which compose our forest or which we desire to plant. We must know what conditions of soil, of moisture, of light they require for their best development; how their growth progresses from the seed to maturity, especially their relative height growth and their light requirement or shade endurance.

The Division engaged, therefore, in 1886, a number of botanists to study and report on the life history of our most important forest trees. But it was soon found that such kind of field study from the forester's point of view was foreign to these men, and although a number of interesting notes were the result of this first venture into field work, their publication had to be deferred until deficiencies in the information could be supplied. In this way the life history of the white pine, of the four important Southern pines, of the two yellow pines of the Northeastern States, of the spruce and the hemlock, of the juniper, of the bald cypress, and of the white cedar were studied.

But so far only the monographs on the Southern pines and that on the white pine have been perfected far enough to be adjudged satisfactory for publication. The magnificent work on the Southern pines, by Dr. Charles Mohr, published as Bulletin 13, furnished a worthy beginning in this line of investigation. It was the first attempt in the United States of a monographic study from a forestry point of view of the economic, technical, and silvicultural conditions and requirements of four species of forest trees.

The monograph on the white pine, being prepared for the press as Bulletin 22 while this report is being written, will in no way be inferior in contents to its predecessor, and several of the other monographs were in a fair way of completion when the writer withdrew from the direction of the Division.

It is upon the basis of such knowledge as these life histories bring that the forester is enabled to apply silvicultural principles in the management of his crop.

In order to apply principles of forest economy he needs more; he must know the capacity of the species for production and the rate of growth in volume. Another line of work, therefore, is necessary to establish this capacity of production by measurements.

FOREST MENSURATION.

The forest crop differs from all other crops, and forestry differs from all other industries of production in two ways. There is, first, no definite period when the crop can be said to be mature, as in the case of agricultural products; it consists of annual accumulations, which are allowed to continue until the individual trees attain either a useful or a profitable size; and, secondly, to attain such size a long time, and with different species and conditions, a variable time is needed. Thus, for firewood production a growth of fifteen to twenty-five years might suffice, while for good lumber production not less than seventy-five to one hundred years and more are needed. This indefiniteness of the time of maturity and the unusually long period of production during which the crop has to grow predicate peculiar business arrangements, entirely different from those prevailing in other industries if forest growing is to be carried on as a financial business, and so necessitate to a greater extent than with any other a full knowledge of the progress of the crop.

Tree measurements, especially measurements of the rate of growth of single trees and of whole stands of trees, furnish the basis for determining the question when under given conditions the useful or the profitable sizes may be expected to be attained, and also the question of quantitative production.

The Division has therefore for some time, as opportunity, men, and money were at its disposal, carried on measurements of the rate of growth of certain species, especially of the important conifers.

In the forthcoming monograph on the white pine a comprehensive statement of the growth of this most important timber tree, based on the analysis of nearly 700 trees from many localities will be found, which will show that this species is capable of producing, under proper management, larger amounts of valuable material in a shorter time than any of the European species.

To establish the amounts which a species can produce in different lengths of time is a much

more complicated matter than most people would suspect, especially since our measurements can only be made on trees and stands of trees which have grown in nature's unattended forests, while with the application of knowledge and skill in the management of the crop quite different results may be secured. A bulletin of the Division, No. 20, has been published describing the methods of measurement of standing trees and forests and of the rate of growth of trees and forests.

There have been many misconceptions abroad as to the rapidity of tree growth and the amounts that may be harvested from an acre in a given time. If wood alone were to be produced the matter would be much more simple. We could, from the experience which has been gathered in other countries and in our own, soon arrive at a statement as to the amount of wood which an acre of a full-grown dense forest crop could produce, just as we know the productive capacity of an acre of wheat or barley.

In an average of a hundred years the yearly growth, according to species, soil, and climatic conditions, would vary between 30 and 180 cubic feet of wood per acre each year. But, unless firewood is the object of forest cropping, it is not quantity of wood merely, but wood of given size and of given quality, wood fit for the arts, that is to be grown. It will only pay to raise wood of this kind. Hence, it is necessary not only to know what sizes can be grown in given periods of the life of the crop and what sizes can be profitably handled at the mill or in the market, but also what qualities are desired and under what conditions they can be produced. Trees develop very differently at different periods of their life. Thus, while a white pine tree may in the first fifty years have grown on an average one-third of a cubic foot of wood per year, if we had waited till the hundredth year the average rate per year would appear as more than 1 cubic foot, and the total volume four to five times what it was at fifty years, although the diameter has only about doubled. Again, while at fifty years hardly more than 15 per cent of the total wood volume would have furnished saw timber, perhaps making 50 feet B. M., at one hundred years the proportion of the more valuable milling material would have risen to 40 per cent and more of the whole tree, and the output of timber would have reached 500 feet B. M. On the other hand, an acre of pine fully stocked which at one hundred years may have produced at the rate of 140 cubic feet per year could under the same conditions have produced for the first fifty years at the rate of 180 cubic feet per year, or nearly one third more. Yet the value of the wood on that same acre at one hundred years is very considerably more than the fifty-year old wood, on account of the increased proportion of highly useful material that can be got from it. Similarly, we find that not more than 1 to 2 per cent of the wood produced in the coppice sprouts of twenty to twenty-five years' growth, in which New England abounds, is serviceable in the arts, while 50 to 75 per cent and more may be thus profitably utilized from the same acre if grown from seed and allowed to grow one hundred years.

It will be readily seen from these few glimpses into the subject that this knowledge of the rate of development and yield of our timber trees is indispensable for the discussion of the profits of forest cropping, and also furnishes hints for rational methods of silviculture. This same white-pine tree, for instance, could have made much more wood if it had been allowed to grow without interfering neighbors, but it would not only have assumed a less useful conical shape, but would have put much of its energy into branches, which not only do not furnish serviceable wood, but produce knotty lumber, an inferior or unsalable article. Moreover, the wood of most or many of our trees changes in quality with age, so that with size, form, and freedom from knots not only the technical value, but the money value also, grows disproportionately.

It will then appear at once that these measurements must precede the discussion of the question most momentous to him who is to be induced to engage in the business of forest cropping, the first and last question asked:

IS FORESTRY PROFITABLE?

It is claimed that if this question were answered in the affirmative, forestry practice would at once be established in this country. Unfortunately it is a question that nobody can answer in general terms. No business is profitable per se; one railroad fails, another pays; for profitableness depends upon a complexity of conditions which are local, and hence without given conditions it is useless to attempt to answer such a question. It has been shown that under the economic and populational conditions of Germany (see Appendix) forestry is—not everywhere, by any

means, but on the whole—a profitable business. There are large forest areas in eastern Prussia which even now do not earn their mere cost of administration, let alone the yielding of a net income on the capital represented. There are considerable areas in the mountains of Bavaria which are so disadvantageously located that they can not compete with the more favorably situated ones, and only because managed by the same owner, the Government, does the management appear profitable. This profitableness is expressed avowedly by a 3 or 4 per cent return on the capital involved which is tied up in the soil and the growing stock of wood that must be maintained, and a smaller return is in many cases considered acceptable, while a larger return is probably rare.

If, then, in a country with dense population, where in many places every twig can be marketed, with settled conditions of market, with no virgin woods which could be cheaply exploited and come into advantageous competition with the costlier material produced on managed properties, with cost of labor low and prices for wood comparatively high—if under such conditions the returns for the expenditure of money, skill, intellect in the production of wood crops is not more promising, it would seem hopeless to develop the argument of profitableness in a country where all these conditions are the reverse, and a business man considers a 6 per cent investment no sufficient inducement.

Another point on which we must agree before discussing the question of profitableness is as to what we shall consider "profitable." The conception as to profits to be expected from investment of capital varies with time and with different economic conditions. In our country, the rapid development of our vast resources has introduced speculative aspects into almost every investment, even in bona fide business transactions, and the investor in business expects still a very much larger return than the low interest rates obtainable for money loans. Only when we are reaching a more settled, permanent civilization will the small but sure returns from such a business as the forestry business recommend themselves especially to the large capitalist who seeks a permanent investment.

From the standpoint of national economy, to be sure, the use of our poor soils, which are capable of producing nothing but wood crops, is profitable, though the money returns may not recommend themselves to the private investor.

Again, if the question were asked, Is it profitable for a farmer to apply silvicultural principles in the cutting of his wood lot so as to reproduce a good second crop? the answer will be without doubt affirmative, provided the soil of the wood lot is not better adapted to agricultural production. So would the answer be to mine operators or furnace managers who own forest property for the purpose of supplying themselves with mine timber or charcoal as an adjunct to their business.

The pulp manufacturer, too, who expects to run his mill continuously and has a definite object and permanent supply of raw material from his forest property to his own business in view, is in the same position; he will find it at least indirectly profitable to apply both silviculture and forest economy from considerations which are conditioned on his own main business. But he who contemplates entering upon the independent business of forest growing to supply the great timber and wood market is in an entirely different position.

The greater part of the forest property in this country is held either by speculators, who are waiting for the opportunity to dispose of the whole, or of the wood on it, who do not hold it as a permanent investment or as a basis for a business, or else by lumbermen, who from necessity or by education are also inclined, and by the momentum of their business methods are forced, not to look at their forest property as a permanent investment or upon their logs as a crop, but to treat it as a mine, a basis, to be sure, but only a speculative basis of their mill business. Only when these realize that there are no more speculative forest areas to be had, that the remaining virgin forest crop is either used up or out of the market, will they feel induced to alter their methods and engage in the production instead of the mere harvesting of wood crops, becoming breeders as well as butchers.

There are other classes of capitalists, now in small numbers, who may, as in older countries, be induced to own and manage large forest properties with a view of practicing forestry, when they have found out that one of the safest investments, although promising only a small interest rate, is in forest properties.

Forestry to be carried on profitably requires the bringing of large areas under one management, as the German governments do; it requires large amounts of capital permanently invested; it can not be carried on as a speculative business. To prove that this is so we need only inspect the comparatively poor results of private forestry in Germany, as given in the Appendix.

Such investments will by and by attract our large capitalists and trusts, when forestry will be carried on as profitably as in the older countries. But this is a matter which necessarily comes slowly and can not be brought about by any argument or action except that of economic changes.

The writer, having had business experience himself, soon became convinced that before a general argument of the profitableness of forestry could be advanced many changes in economic conditions must take place, among which must be especially a further reduction in virgin supplies and the establishment of the fact of a threatened scarcity of the same; in other words, an absolute necessity for the application of the art of forestry and also a change in the attitude toward investments in general from a speculative to a permanent character.

He, therefore, was impressed the more with the necessity of Government action to counteract the destructive tendencies and to provide for the future, and also with the need of knowledge as to our actual supplies on hand.

This knowledge can be had with satisfactory precision only by the expenditure of sufficient funds, as intimated before. These, in spite of the urgent presentations of the matter could never be secured; the Census of 1880 had attempted the task with insufficient funds, at least with reference to certain classes of supplies, and the results, rightly or wrongly, were promptly discredited.

The census authorities of 1890, being requested to fill this important gap in our knowledge of the country's condition, did not consider the matter as a proper one to be included in its investigations—the greatest source of wealth next to agriculture being thus neglected—although many inferior industries were thoroughly canvassed. The Division of Forestry was, therefore, in this particular reduced to taking information second-hand and to attempt the various estimates, which have been discussed in the earlier part of this report, and some of which are rehearsed in the appendix.

Whatever argument could be brought to induce the Government to at least take care of its own holdings was employed in reports, bulletins, and statements before Senate and House committees. Notably in Bulletin 2, which describes in detail the conditions of the Rocky Mountain forests, mainly the property of the Federal Government, the duty of the State with reference to the property has been fully discussed, and finally through these efforts, assisted by other agencies, the Government was committed to the policy of forest reservations, happily inaugurated in 1891.

For the Government, to be sure, other than financial considerations are paramount, and it can well afford, for cultural and economic reasons, to maintain forest reservations, even if they do not pay, or if they do not pay the rate of interest which the private business man expects from his venture.

TREE PLANTING IN THE PLAINS.

While we may, then, leave the development of this part of forest economy—the demonstration of its financial profitableness—to the next generation, there is the indirect profit which comes to the farmer or owner of land in stocking the poor parts of his property with a crop which will produce, if not an interest, yet an effect on the rest of his property. The settler in the forestless plains, especially, will pursue tree planting for the purpose of ameliorating his surroundings. Considerable attention has, therefore, been paid to developing silvicultural methods under the conditions prevailing in the plains.

This tree planting has in view protection from cold and hot winds, shade and shelter, rather than wood supplies, and we may as well recognize at once the fact that, while undoubtedly this beneficial influence of timber belts may be secured in most parts of the arid and subarid belts, and incidentally the supplying of firewood and other timber of small dimensions for domestic use, it is entirely out of the question to expect that these plantings will ever furnish supplies for our great lumber market. These supplies will always, the writer believes, be grown in the regions in which forests now grow and which are by nature best adapted to wood crops.

In these arid and subarid regions, where nature has denied tree growth, the climatic conditions are so different from those of the humid parts that not only different methods of cultivation

are necessary, but the plant material must be imported and selected with a view to a rigorous climate, characterized by extreme ranges of temperature. A range of 40° below zero to 120° F. above must be endured by the trees, their moisture requirements must be of the smallest, and they must be capable of responding to the enormous demands of evaporation. At first, whatever trees will grow successfully from the start under such untoward conditions would have to be chosen, no matter what their usefulness otherwise might be.

The first settlers have ascertained by trials some of the species that will succeed under such conditions, but unfortunately most of these are of but small economic value and some of them are only short-lived under the conditions in which they have to grow. The methods of planting were naturally suggested by the experience of orchardists and nurserymen, since forest planting had never been practiced in this country; but unquestionably many failures can be avoided by application of forestry principles in these plantings. Whether more useful kinds can be found that may be grown to advantage, and whether methods of planting can be devised by which a greater efficiency of the plantation may be gained, are problems which the Division has taken up within the last few years. Such problems can, of course, only be solved by actual field work, experiment, or trial, and hence the cooperation of the State agricultural experiment stations was secured to carry on such experiments. The station authorities have placed some land at the disposal of the Department, and the professors of horticulture or some other officer of the station superintends, free of charge, the labor of planting, cultivating, etc., while the Division of Forestry furnishes the plans, plant material, and all expenses.

So far, the stations of Montana, Utah, Colorado, Texas, Oklahoma, Kansas, Nebraska, South Dakota, and Minnesota are engaged in this cooperative work. In addition, there are two planting stations located in the forested regions, namely, one in Minnesota and one in Pennsylvania, to experiment on practical methods of reforesting cut-over waste brush lands.

Some few years ago the writer came to the conclusion that the conifers, especially the pines, would furnish more useful and otherwise serviceable plant material for the arid regions. Not only are they of greater economic value than most of the deciduous trees that have been planted, but, requiring less moisture for their existence, they would, if once established, persist more readily through droughty seasons and be longer lived; besides, their persistent foliage would give more shelter all the year around.

A small trial plantation on the sand hills of Nebraska, described in the annual reports of the Division for 1890 and 1891, lent countenance to this theory. To be sure, the difficulty of establishing the young plants in the first place is infinitely greater than would be experienced with most deciduous trees. A large amount of attention was, therefore, devoted to finding practicable methods of growing the seedlings cheaply for extensive use and of protecting them for the first few years in the plantations; for the transplanting of conifers is attended with considerable difficulties, especially in a dry climate, and they require protection from the sun and winds during the first few years. They must, therefore, be planted in mixture with "nurse" trees which furnish not too much and yet enough shade. It can not be said that the success in using these species has so far been very encouraging; nevertheless, the failures may be charged rather to our lack of knowledge and to causes which can be overcome than to any inherent incapacity of the species. The experimentations should, therefore, be persistently continued.

Mixed planting and close planting are undoubtedly the proper methods of quickly establishing forest conditions, when without further attention the plantation will take care of itself. But it is essential to know what species should be planted together and how closely in order to secure the best results, and this knowledge can only come from experience and actual trial, since the behavior of trees in regions in which they are not indigenous can not be predicted by anyone.

The results of these trial plantings have been discussed at great length, in Bulletin 18 of the Division, by Mr. Charles A. Keffer, who has been in charge of this particular work. Other minor investigations and experiments calculated to increase our silvicultural knowledge for the benefit of the forest producer were also carried on, and the introduction of special strains of basket osiers, of tan-bark wattle trees, of cork oak, and Eucalyptus seed, as well as the distribution of seeds and seedlings to would-be planters—to be sure only in small amounts as justified by the small appropriation—belong to this work of silvicultural advancement.

DISTRIBUTION OF PLANT MATERIAL.

There is no doubt that to the settler on the treeless plain the supply of plant material could be made an effective incentive to forest planting, but it would have to be done on a different scale from that which has been practicable under the appropriations for the Division. Distribution of plant material for agricultural use and for forest planting differs in principle as well as in object. While seed distribution in the first case may be desirable for the purpose of introducing new kinds and improving the character of agricultural crops, this can only exceptionally be the purpose in the distribution of forest-plant material. The native trees are almost invariably the best to plant. The object of the distribution would be to induce the planting of a crop which without such special inducement would not be planted at all. Moreover, the handling of tree seeds is connected with greater difficulties than of agricultural seeds, and planting of seedlings rather than of seed is the proper procedure.

Since forest planting means planting on large areas, if there is to be any result, and requires a large number of plants to the acre—not less than 2,000—it is at once apparent that the Division could not supply the plant material for many acres or to many applicants. After useless and discouraging attempts to comply with the law, the effort was abandoned and the provision remained a dead letter, except when there could be secured seeds or plants of certain kinds, the adaptability of which to certain climatic conditions was desired to be tested.

TREES FOR THE ARID REGIONS.

In 1897, at the request of the Secretary of Agriculture to devise means of finding the trees best adapted for planting in arid regions, including in this term probably all parts of the dry country west of the 100th meridian, which is practically treeless, the writer submitted a plan, which would at least insure a comprehensive and systematic basis for the accomplishment of the final object. It contemplated the establishment of a series of arboreta in various parts of that dry region, where the arborescent flora of the arid regions of the world might be assembled and tested, after thorough study of the climates of the regions where this plant material was to be collected by competent men. A competent gentleman was secured to carry out this plan, the methods and objects of which are more fully set forth in Bulletin 21 of the Division of Forestry. This plan, devised for a specific line of introduction of exotics, recommended itself so well for general application in the work of plant introduction that it has been developed as a special branch of the Seed Division, where now, with special appropriations, the whole question of plant importation is placed on a systematic basis.

PROPAGANDA WORK.

A large amount of attention, time, and energy has been spent by the Division and its chief to secure recognition of its field and to elucidate its meaning, its importance, and its methods before legislators, before associations, before the public, and in the technical and daily press.

Its exhibits at the various expositions at New Orleans, at Cincinnati, at Paris, at Chicago, at Atlanta, at Nashville, at Omaha, have perhaps had as much effect in bringing the subject home to the people as its printed utterances.

While the many addresses and lectures delivered before associations and other public meetings, the many articles furnished to magazines and journals, the many arguments and statements presented before legislative committees, may perhaps hardly be considered as work of an official nature, nevertheless they did their share in advancing correct ideas among the people quite as much as if they had been uttered officially. The reiteration of the same truths in different garb is necessary if we desire to secure a reform, and every means must be seized upon if we desire to educate a large public. The Division, therefore, identified itself with every movement which was started in the same direction, in which its official functions directed it. It became the acknowledged assistant of all such movements.

In thus molding public opinion it became instrumental in committing legislatures and governments to take an interest in forestry matters and to consider legislation in their behalf.

While eventually many other influences became active in forwarding the forestry movement, it will not be denied that the first and the most active factor in advancing forestry reform has been the Division of Forestry.

INFLUENCE OF THE DIVISION OF FORESTRY ON THE FORESTRY MOVEMENT.

In 1876, when the first agency to report on forestry was established in the Department, the very word "forestry" was absent from the dictionaries, and the word "forester" was defined as "an officer appointed to watch a forest or chase and to preserve the game (English)."

The idea of an art by that name and of its objects and methods did not exist among our people, except with a few who had traveled abroad.

To-day there is hardly a week when not one or more of the daily journals discuss with considerable familiarity some phase of interest pertaining to forestry, and it has become a matter of daily conversation, a topic of public lectures and magazine articles.

That the Division has been the most potent influence in bringing about this change can be readily shown by the constant references to it when the subject is discussed, by the voluminous quotations from its publications, and by the uncredited, nevertheless often almost verbatim, restatements of its utterances by writers for the public press.

There are in existence now one national (since 1882) and a number of State and local forestry associations engaged in promoting the subject in their various spheres of action. The Division, or at least its chief, has been either an active member or officer of some of these organized bodies, or else has been instrumental or helpful in bringing them into existence or assisting with advice or contributions to their programme.

Many other associations organized for the promotion of allied purposes discuss the subject of forestry at their meetings, and their proceedings show not only the stimulating influence of the work of the Division, but contain a large number of contributions to their publications from the same source.

Some twenty agricultural colleges have incorporated into their courses lectures on forestry, and "professors of forestry," usually the botanist or horticulturist, at these institutions impart their knowledge of the subject in either elective or required courses. The publications of the Division, being the most available technical literature in the country, serve largely as the basis of these lectures or even as text-books.

The State of New York has gone a step further and has this year established a fully organized professional school, the State College of Forestry at New York University, inviting the then chief of the Forestry Division to assume its directorship. The course prescribed for students who desire the degree of bachelor in the science of forestry is as full as any in other similar branches and as complete as those given at the best forestry schools of Germany. (See Appendix.)

With the establishment of this first professional school of forestry we may say that the art of forestry, not merely as a matter for discussion, is engrafted upon our system and a new era in the movement for rational forestry methods is begun.

The most important feature of this novel educational venture is an experimental area of 30,000 acres specially set aside to demonstrate the methods of silviculture and forest economy, so as to serve as a model eventually for the rest of the State property.

FORESTRY LEGISLATION.

Forest fires have been the bane of American forests. It is estimated that more wood has been burned up in the yearly conflagrations than has been utilized. There could be no expectation of applying rational forestry methods until forest property is protected against immediate loss and destruction by fire. There were laws against incendiaries on the statute books of nearly every State, but they were inoperative and inefficient. The first effective law against forest fires in active operation was drafted by the writer in 1885 for the State of New York, and was inaugurated the same year. It provided for a well organized system to suppress fires. Substantially the same law, with minor modifications, has been adopted by the States of Maine, New Hampshire, Wisconsin, and Minnesota, the Forestry Division being at least the means of making the methods known through its reports and correspondence.[1]

Nine States have special forestry commissions or other agencies charged with taking care of the forestry interests of their States or else to investigate and report on desirable legislation, and three or four other States have charged some existing commission with similar duties. In many

[1] For this legislation and other specific information regarding conditions in the United States see Appendix.

if not most cases the legislation leading to these commissions has been either formulated or suggested by the writer, or at least supported by arguments and facts drawn from the Division.

The State of New York has set aside a forest reserve of over 1,000,000 acres, and is adding yearly to it by purchase, intending to increase it ultimately to 3,000,000 acres.

The legislation establishing the first commission to take charge of the forest property of the State was formulated by the writer in 1885 at the request of State Senator Low, who secured its passage, while several other bills drawn for the same purpose were tabled.

The State of Pennsylvania has last year followed the example and launched into a similar policy. It has purchased, or is about to purchase, a number of forest reservations, which are placed under the management of the active forest commissioner.

The Federal Government finally has reserved 38,000,000 acres of the public timber lands as forest reservations. While to commit our Government to such a policy, which would twenty years ago have appeared entirely foreign to our ideas of government functions, could hardly have been accomplished by any one agency, nevertheless the result has been undoubtedly an effect of the educational campaign carried on mainly by the Division.

Dr. Hough, in his third report, suggested the withdrawal of all public timber lands and discussed principles for their management. In 1886 the present writer formulated further methods of management (see page 164, Report of the Commissioner of Agriculture for 1886), and in 1887 framed a comprehensive bill which was presented to Congress and advocated through the American Forestry Association. This bill, afterwards known as the Paddock bill[1] later modified into the so-called McRae bill,[2] contains the features upon which all subsequent legislation regarding forest reserves has been based.

The section of the law of March 3, 1891, which establishes the policy of forest reservations was formulated by the then Secretary of the Interior who publicly and in print[3] acknowledged his indebtedness for the idea to the educational influence referred to.

In securing the first reservations to the extent of nearly 20,000,000 acres, the American Forestry Association and the chief of the Division, at the same time the chairman of the executive committee of the Association, were most active, as may be learned from the files in the General Land Office.

Several bills providing for the administration of these forest reserves were also formulated and supported by argument before the Public Lands Committee of both House and Senate, and the passage of one of these in both Houses was secured in 1895, failing to become a law only from lack of time to secure a conference report.

While the influence of other agencies in bringing about these various advances toward a forestry system in the United States is not denied or undervalued, the writer, as a fair historian, has found it necessary to assume the position of seeming self-glorification. It was impossible to dissociate the personal efforts of the chief from the work of the Division, and it was also impossible to offer a justification for the existence of the Division, as was evidently required by the clause in the act of 1897 calling for this report, without tracing in definite directions the tangible results which its work has secured, directly or indirectly.

In addition to the unquestionable advancement in educational and legislative direction, the Division has also produced as described an amount of valuable technical information, which in itself is believed to furnish ample justification for its past existence.

Finally, it should be stated that a small number of timber-land owners have ventured to place their woodlands under management. While in most of these cases the Division had no direct relation to the undertaking, its long-continued educational campaign, which made it apparent that decreasing supplies can only be met by intelligent recuperative methods, must have had its effect in inducing such beginnings.

In conclusion, I may be permitted upon my retirement from the direction of its work to characterize the past period of twenty years of the existence of the Division as the period of propaganda and primary education. We have during this period made the beginnings for a new departure,

[1] S. 2367, Fifty-first Congress.

[2] See page 15 of the Report of the Division of Forestry for 1887.

[3] See Proceedings American Forestry Association, vol. 10.

for an economic reform. We have laid the foundations upon which it will be possible to build a superstructure.

Many things which were not possible, or would not have been timely to attempt before, can now be done because circumstances have changed, people have become educated, their minds have become receptive. Educated foresters, who were not at the command of the Division during the past period, can now be found in sufficient numbers to carry on technical work, which was impracticable, nay impossible, before.

While at first the Division of Forestry was the only educational element in the forestry movement, it may now, perhaps, be left to other agencies to carry on a general propaganda and campaign of enlightenment, and the Division can concentrate itself more upon the development of the technical side of forestry.

Finally, however, a Division of Foresty in a Government which has reserved millions of acres of forest property must logically become the manager of that forest property, leaving the development of technical detail to a minor branch or to other institutions.

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APPENDIX

TO

REPORT ON FORESTRY INVESTIGATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

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A. MEMORIAL TO CONGRESS.

MEMORIAL OF A COMMITTEE OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE ON BEHALF OF FOREST PRESERVATION, LEADING TO THE ESTABLISHMENT OF THE DIVISION OF FORESTRY.

[From Senate Ex. Doc. 28, first Session Forty-third Congress, or Report No. 259, H. R., first Session Forty-third Congress.]

At the meeting of the Association for the Advancement of Science held at Portland, Me., on the 22d day of August, 1873, the following resolution was passed:

Resolved, That a committee be appointed by this association to memorialize Congress and the several State legislatures on the importance of promoting the cultivation of timber and the preservation of forests, and to recommend such legislation as may be deemed proper for securing these objects. Also, that this committee be instructed to cooperate with national associations for a similar object.

The committee appointed consisted of Franklin B. Hough, Lowville, N. Y.; George B. Emerson, Boston, Mass.; Prof. Asa Gray, Cambridge, Mass.; Prof. J. D. Whitney, San Francisco, Cal.; Prof. J. S. Newberry, New York City; Hon. Lewis H. Morgan, Rochester, N. Y.; Col. Charles Whittlesey, Cleveland, Ohio; Prof. William H. Brewer, New Haven, Conn., and Prof. E. W. Hilgard, Ann Arbor, Mich.

Under this appointment consultation has been had among members of this committee, who have requested the undersigned, on their behalf, to represent as follows:

That the preservation and growth of timber is a subject of great practical importance to the people of the United States, and is becoming every year of more and more consequence, from the increasing demand for its use; and that while this rapid exhaustion is taking place, there is no effectual provision against waste or the renewal of supply.

We apprehend that the time is not distant when great public injury must result from this cause, and we deem it to be our duty to urge upon the Government the importance of taking timely action in providing against the evils that must otherwise follow.

Besides the economical value of timber for construction, fuel, and the arts, which is obvious without suggestion, and must increase with the growth of the nation, there are questions of climate that appear to have a close relation to the presence or absence of woodland shade. The drying up of rivulets, which feed our mill streams and navigable rivers and supply our canals, the failure of the sources which supply our cities with pure water, and the growing tendency to floods and drought resulting from the unequal distribution of the rainfalls since the cutting off of our forests are subjects of common observation.

In European countries, especially in Italy, Germany, Austria, and France, where the injuries resulting from the cutting off of timber have long since been realized, the attention of governments has been turned to this subject by the necessities of the case, and conservative measures have in many instances been successfully applied, so that a supply of timber has been obtained by cultivation, and other benefits resulting from this measure have been realized.

Special schools of forestry have been established under the auspices of government, and the practical applications of science in the selection of soil and conditions favorable for particular species, and in the planting, care, and removal of timber, are taught and applied, with the view of realizing the greatest benefits at the least expense.

There is great danger that, if not provided against, the fearful changes may happen to our largest rivers which have taken place on the Po and other large rivers of Italy, France, and Spain, caused by the destruction of the forests from which came their tributaries. These forests had retained the water from the snows and rains of winter and spring, and supplied it gradually during the summer. Since their destruction the rain falling in the rainy season comes down almost at once, bringing with it earth and stones, deluging the banks of the larger streams, but leaving a very insufficient provision for evaporation and against the consequent drought of summer.

Thus, when the forests about the sources of our great rivers shall be cut away, the water from the melting snows and early rains will be liable to come down in vast floods, overflowing the banks and carrying ruin and destruction in their course, while the affluent streams in summer will diminish or disappear, to the great injury of the country through which they flow.

We deem it highly important that the true condition and wants of the country in this regard, and the injuries that may result from the destruction of the forests and the exhaustion of our supplies of timber, should be known in time to provide a remedy before the evils are severely felt. There are facts of the greatest importance in relation to the past and present destruction of forests, the pressing want of timber trees in States without natural forests, and the changes that have taken place, or are taking place, in consequence of the destruction of the forests, that should be carefully collected and be widely and familiarly known.

A knowledge of these facts would be everywhere of great value. They should be gathered, arranged, and so widely published as to reach the intelligent inhabitants of all the States. There is not a State or Territory without a direct interest in the subject. We should know the experience of other countries and be able to apply whatever may be found therein suited to our soil and climate and consistent with the plan of our government and the theory of our laws.

Individual or associated effort, unless organized and directed by authority, could not be expected to conduct these inquiries or make known the results with that fullness which the investigation would require. We therefore recommend them as worthy of the attention of Congress, as the immediate guardian of the Territories and the proper source of power in whatever concerns the interest of the whole country.

We would therefore respectfully request the passage of a law creating a commission of forestry, to be appointed by the President and Senate, and that it should be required to ascertain, from the most effectual and reliable means within its power, and to report to Congress upon the following subjects:

First. Upon the amount and distribution of woodlands in the United States, the rate of consumption and waste, and the measures that should be adopted to provide against the future wants of the country in the preservation and planting of timber. With this there should be an inquiry concerning the importation and exportation of lumber and other forest property.

Second. The influence of forests upon the climate, and especially as to what extent their presence or absence tends to affect the temperature, rainfall, and other atmospheric conditions upon which agricultural success depends.

Third. A full statement of the methods practiced in Europe in relation to the planting and management of forests, and an account of the special schools of forestry that have been established in foreign countries.

Respectfully submitted.

FRANKLIN B. HOUGH,
GEO. B. EMERSON,

On Behalf of the Committee of the American Association for the Advancement of Science.

WASHINGTON, D. C., *February 6, 1874.*

JOINT RESOLUTION for the appointment of a commission for inquiry into the destruction of forests and into the measures necessary for the preservation of timber.

Whereas it is asserted that the supply of timber within the United States is rapidly diminishing, and that great public injury must result from its continued waste, without adequate means being taken for its preservation and production: Therefore,

Be it resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the President be, and he is hereby, authorized and required to appoint, by and with the advice and consent of the Senate, a man of approved scientific and practical acquaintance with statistical inquiries, to be commissioner of forestry.

SEC. 2. *And be it further resolved,* That it shall be the duty of said commissioner to prosecute investigations and inquiries on the subject with the view of ascertaining the annual amount of consumption, importation, and exportation of timber and other forest products; the probable supply for future wants; the means best adapted to its preservation and renewal; the influence of forests upon climate, and the measures that have been successfully applied in foreign countries for the preservation and restoration of forests; and to report upon the same to Congress.

SEC. 3. *And be it further resolved,* That the heads of the Executive Departments be, and they are hereby, directed to cause to be rendered all necessary and practicable aid to the said commissioner, by access to the public records and otherwise, in the prosecution of the investigations and inquiries aforesaid.

B. LIST OF PUBLICATIONS RELATING TO FORESTRY ISSUED FROM THE DEPARTMENT OF AGRICULTURE SINCE 1877.

BULLETINS.

No. 1. Report on the Relations of Railroads to Forest Supplies and Forestry, together with appendices on the structure of some timber ties, the behavior and the cause of their decay in the roadbed, on wood preservation, on metal ties, and on the use of spark arresters, by B. E. Fernow. Pp. 149, pls. 7, figs. 7. 1887.

No. 2. Report on the Forest Conditions of the Rocky Mountains, with a map showing the location of forest areas on the Rocky Mountain range, and other papers. Pp. 252, map, 1, diagr., 1. 1888.

Contents: Extracts from Reports of the Commissioners of the Land Office—The Government in its relation to forests, by Prof. E. J. James—Report on the forest conditions of the Rocky Mountains, by Col. Edgar T. Ensign—Map showing the location of forest areas and principal irrigation ditches in the Rocky Mountain region—Forest flora of the Rocky Mountains, by George B. Sudworth—Report on the forests of Los Angeles, San Bernardino, and San Diego counties, Cal., by Abbott Kinney—Trees and shrubs of San Diego County, Cal.—The needs of the Yellowstone National Park, by Arnold Hague, geologist in charge—Summary of legislation for the preservation of timber or forests on the public domain, by N. H. Egleston—The climate of Colorado and its effects upon trees, by George H. Parsons—Snow slides or avalanches, their formation and prevention, by B. E. Fernow.

No. 3. Preliminary Report on the Use of Metal Track on Railways as a Substitute for Wooden Ties, by E. E. Russell Tratman, C. E., to which is added a report of experiments in wood seasoning by the Chicago, Burlington and Quincy Railroad Company, and other notes. Compiled by B. E. Fernow. Pp. 79, diagr. 6. 1889.

No. 4. Report on the Substitution of Metal for Wood in Railroad Ties, by E. E. Russell Tratman, C. E., together with a discussion on practicable economies in the use of wood for railway purposes, by B. E. Fernow. Pp. 363, pls. 30. 1890.

No. 5. What is Forestry, by B. E. Fernow, Chief of Division of Forestry. Pp. 52. 1891.

No. 6. Timber Physics. Part I. Preliminary Report. Compiled by B. E. Fernow, Chief of Division of Forestry. Pp. 61, pls. 6, figs. 12. 1892. 4°.

1. Need of investigation. 2. Scope and historical development of the science of "timber physics." 3. Organization and methods of the timber examinations in the Division of Forestry.

No. 7. Forest Influences. Pp. 197, figs. 63. 1893.

1. Introduction and summary of conclusions, by B. E. Fernow. 2. Review of forest meteorological observations, a study preliminary to the discussion of the relations of forest to climate, by M. W. Harrington. 3. Relation of forest to water supplies, by B. E. Fernow. 4. Notes on the sanitary significance of forests, by B. E. Fernow. Appendices: 1. Determination of the true amount of precipitation and its bearing on theories of forest influences, by Cleveland Abbe. 2. Analysis of rainfall with relation to surface conditions, by George E. Curtis.

No. 8. Timber Physics. Part 2. Pp. 92, pls. 12, figs. 22. 1893. Progress report: Results of investigations on long-leaf pine.

Contents: Mechanical tests made at Washington University testing laboratory, St. Louis, by J. B. Johnson—Field report on turpentine timber, by F. Roth—Resinous contents and their distribution in the long-leaf pine, by M. Gomberg—Field records of test material, by C. Mohr.

No. 9. Report on the Use of Metal Railroad Ties and on Preservation Processes and Metal Tie-plates for Wooden Ties. By E. E. Russell Tratman, A. M., Am. Soc. C. E. (supplementary to report on the Substitution of Metal for Wood in Railroad Ties, 1890). Prepared under the direction of B. E. Fernow, Chief of Division of Forestry. Pp. 363, pls. 5. 1894.

No. 10. Timber: An Elementary Discussion of the Characteristics and Properties of Wood. By Filibert Roth, special agent in charge of Timber Physics. Under the direction of B. E. Fernow, Chief of Division of Forestry. Pp. 88, figs. 49. 1895.

No. 11. Some Foreign Trees for the Southern States. (Cork, Wattle Tree, Eucalyptus, Bamboo.) Prepared under direction of B. E. Fernow, Chief of Division of Forestry. Pp. 32, pls. 3. 1895.

No. 12. Economic Designing of Timber Trestle Bridges, by A. L. Johnson, C. E. Pp. 57, figs. 7. 1896.

No. 13. The Timber Pines of the Southern United States, by Chas. Mohr, Ph. D. Together with a Discussion of the Structure of their Wood, by Filibert Roth. Prepared under the direction of B. E. Fernow, Chief of Division of Forestry. Pp. 160, pls. 27, figs. 18. 1896.

No. 14. Nomenclature of the Arborescent Flora of the United States, by George B. Sudworth, dendrologist of the Division of Forestry. Prepared under the direction and with an Introduction by B. E. Fernow, Chief of Division of Forestry. Pp. 8, 419. 1897.

No. 15. Forest Growth and Sheep Grazing in the Cascade Mountains of Oregon, by Frederick V. Coville. Pp. 54. 1898.

No. 16. Forestry Conditions and Interests of Wisconsin, by Filibert Roth, special agent. With a discussion of objects and methods of ascertaining forest statistics, etc., by B. E. Fernow, Chief of Division of Forestry. Pp. 76, map of forest distribution in Wisconsin. 1898.

No. 17. Check List of the Forest Trees of the United States, their Names and Ranges, by George B. Sudworth, dendrologist of the Division of Forestry. Prepared under the direction of B. E. Fernow, Chief of Division of Forestry. Pp. 144. 1898.

No. 18. Experimental Tree Planting in the Plains, by Charles A. Keffer, assistant chief of the Division. Prepared under the direction of B. E. Fernow, Chief of Division of Forestry. Pp. 94, pls. 5, figs. 1. 1898.

No. 19. Osier Culture, by John M. Simpson. Prepared under the direction of B. E. Fernow, Chief of Division of Forestry. Pp. 27. 1898.

No. 20. Measuring the Forest Crop, by A. K. Mlodziansky. Prepared under the direction of B. E. Fernow, Chief of Division of Forestry. Pp. 70, figs. 16. 1898.

No. 21. Systematic Plant Introduction, by David A. Fairchild, special agent. Prepared under the direction of B. E. Fernow, Chief of Division of Forestry. Pp. 24. 1898.

No. 22. The White Pine, a monograph, by V. M. Spaulding. Revised and enlarged by B. E. Fernow, with contributions by Filibert Roth and F. A. Chittenden. (In press.)

No. 23. The Uses of Wood in Mining and in the Charcoal Iron Industries, by John Birkinbine, C. E. With a discussion of methods of forest management applicable to woodlands subserving these industries by B. E. Fernow, Chief of Division of Forestry. (In press.)

CIRCULARS OF INFORMATION.

No. 1. Request to Educators for Cooperation.

No. 2. A Circular to Educational Men.

No. 3. Increasing the Durability of Timber (information to wood consumers). Pp. 4. 8°.

No. 4. For Information of Railroad Managers (use of chestnut oak for railroad ties). Pp. 3. 4°.

No. 5. Arbor Day Planting in Eastern States. Pp. 4. 4°.

No. 6. Instructions for Growing Tree Seedlings. Pp. 4. 4°.

No. 7. The Government Timber Tests. Pp. 4. 8°.

No. 8. Strength of "Boxed" or "Turpentine" Timber. Pp. 4. 8°.

No. 9. Effect of Turpentine Gathering on the Timber of Longleaf Pine. P. 1. 8°.

No. 10. Suggestions to the Lumbermen of the United States in Behalf of More Rational Forest Management. Pp. 8. 8°.

No. 11. Facts and Figures Regarding Our Forest Resources, Briefly Stated. Pp. 8. 8°.

No. 12. Southern Pine: Mechanical and Physical Properties. Pp. 12. 4°.

No. 13. Forest Fire Legislation in the United States. Pp. 8. 8°.

No. 14. Is Protection Against Forest Fires Practicable? Pp. 4. 8°.

No. 15. Summary of Mechanical Tests on Thirty-two Species of American Woods. Pp. 12. 4°.

No. 16. Age of Trees and Time of Blazing Determined by Annual Rings. Pp. 11. 8°.

No. 17. Recent Legislation on State Forestry Commissions and Forest Reserves. Pp. 16. 8°.

No. 18. Progress in Timber Physics: Influence of Size on Test Results; Distribution and Effect on Strength of Moisture; Maximum Uniformity of Wood; Relation of Compression Endwise Strength to Breaking Load of Beam. Pp. 20. 4°.

No. 19. Progress in Timber Physics: Bald Cypress. Pp. 24. 4°.

No. 20. Increasing the Durability of Timber. Pp. 5. 8°.

CHARTS.

The lessons of erosion due to forest destruction. Three colored charts, 30½ by 48½ inches, showing: (1) How the farm is lost; (2) how the farm is regained; (3) how the farm is retained. 1896.

REPORTS ON FORESTRY.

Vol. I. Report upon Forestry, prepared under the direction of the Commissioner of Agriculture, in pursuance of an act of Congress approved August 15, 1876. By Franklin B. Hough. Pp. 650. Index. 1878.

Vol. II. Report upon Forestry, prepared under the direction of the Commissioner of Agriculture, in pursuance of an act of Congress approved August 15, 1876. By Franklin B. Hough. Pp. 618. Index. 1880.

Vol. III. Report upon Forestry, prepared under the direction of the Commissioner of Agriculture, in pursuance of an act of Congress approved August 15, 1876. By Franklin B. Hough. Pp. 318. Index. 1882.

Vol. IV. Report upon Forestry, prepared by N. H. Eggleston. Pp. 421. Index. 1 map. 1884.

ANNUAL REPORTS OF CHIEF OF DIVISION OF FORESTRY.

[For years 1884–1893, inclusive, in annual reports of the Secretary of Agriculture for those years. For years 1894–1896, inclusive, in messages and documents for those years. For 1897, in annual reports of Department of Agriculture for 1897.

Same, issued separately in pamphlet form for the years 1886, 1887, 1888, 1889, 1890, 1891, 1892, 1893, 1894, 1895, 1896, 1897.

From 1894 these reports refer only to administrative business; before that year they contain technical matter.]

The following subjects are more fully treated in these reports:

Report for 1886—
- Forestry problems of the United States.
- General principles of forestry.
- List of ninety most important timber trees of the United States.
- Osier culture.

Report for 1887. (Special, not printed in report of Department of Agriculture)—
- Trade notes and tariff on lumber—mill capacity of United States.
- Systematic plan of forestry work.
- Tree notes.
- Condition of forestry interests in the States.

Report for 1888—
- Forest influences.
- Cultural and trade notes.

Report for 1889—
- Seedling distribution.
- Timber-culture acts.
- Osier culture.
- Influence of forests on water supplies.

Report for 1890—
- Wood-pulp industry.
- Tests of Northern and Southern oak.
- Forestry education.
- Artificial rainfall.

Report for 1891—
  Forestry lectures.
  Poisoning of street trees.
  Bamboo as substitute for wood.
  Forest-planting experiments in Nebraska.
  Southern lumber pines.
  Forest reservations and their management.
Report for 1892—
  Forest conditions of the United States and the forestry movement.
  Forest-fire legislation.
  Report on Chickamauga National Park.
  The naval-store industry.
Report for 1893—
  Methods of forest measurement.
  Consumption and supply of forest products in the United States.
  German forest management.

ARTICLES REPRINTED FROM YEARBOOKS.

From Yearbook, 1894:
  Forestry for farmers. By B. E. Fernow. Pp. 40, figs. 15.
From Yearbook, 1895:
  The relation of forest to farms. By B. E. Fernow. Pp. 8.
  Tree planting on the Western plains. By Chas. A. Keffer. Pp. 20.
From Yearbook, 1896:
  Tree planting in waste places on the farm. By Chas. A. Keffer. Pp. 18.
  The uses of wood. By Filibert Roth. Pp. 30, figs. 7.
From Yearbook, 1897:
  Division of forestry; relation of its work to the farmer. By B. E. Fernow, chief. Pp. 20.
  Trees of the United States important in Forestry. By Geo. B. Sudworth. Pp. 26.

FARMERS' BULLETIN.

No. 67. Forestry for farmers. Pp. 48, figs. 15.

MISCELLANEOUS PUBLICATIONS.

Catalogue of the Forest Trees of the United States which usually attain a height of 16 feet or more, with notes and brief descriptions of the more important species. 1876. Pp. 38.

Preliminary Report on the Forestry of the Mississippi Valley and Tree Planting on the Plains. By F. P. Baker and R. W. Furnas. Pp. 45. 1883.

Arbor Day, its History and Observance. By N. H. Egleston. Pp. 80, figs. 12. 1896.

Miscellaneous Special Report No. 5. The proper value and management of Government timber lands and the distribution of North American forest trees, being papers read at the United States Department of Agriculture May 7 and 8, 1884. Pp. 47. 1884.

Miscellaneous Report No. 10. A descriptive catalogue of manufactures from native woods, as shown in the exhibit of the United States Department of Agriculture at the World's Industrial and Cotton Exposition at New Orleans, La. By Charles Richards Dodge. Pp. 81. 1886.

Trees of Washington, D. C. By B. E. Fernow and Geo. B. Sudworth. Unp. pl. 1891.

Forestry in the United States. By B. E. Fernow. Report of United States commissioners to the Universal Exposition of 1889 at Paris. Vol. V, pp. 747–777, pls. 6. 1891.

Timber physics.—Preliminary report: Need of investigation. By B. E. Fernow. (From Forestry Bul. No. 6.) Quarto, 16 pp. 1892.

Letter to the Secretary of Agriculture regarding Forest Growth and Timber Consumption. By B. E. Fernow. Pp. 3. 1893.

Instructions for the Collection of Test Pieces of Pines for Timber Investigations. n. d. Pp. 4.

List of Publications relating to Forestry in the Department Library. Prepared under the direction of the Librarian. Pp. 93. 1898.

STATEMENTS BEFORE CONGRESSIONAL COMMITTEES AND IN ANSWER TO SENATE RESOLUTIONS.

Statement on the relation of irrigation problems to forest conditions by B. E. Fernow, before Special Senate Committee on Irrigation and Reclamation of Arid Lands. Fifty-first Congress, first session. Senate Report No. 928, vol. 4, 1890. Pp. 112–124.

Statements in Report No. 1002, Fifty-second Congress, first session. (To accompany S. 3235) "to provide for the establishment, protection, and administration of public forest reservation, and for other purposes." Pp. 12. 1892.

Senate Document No. 172, Fifty-third Congress, second session. Letter from the Secretary of Agriculture . . . transmitting information in relation to investigations and experiments in the planting of native pine seed in the sand hills of the Northwest. Pp. 14. 8°. 1894.

Statements in House Report No. 1442, Fifty-third Congress, second session. Investigations and Tests of American Timbers. Pp. 4. 1894.

Statements in House Report No. 897. Public Forest Reservations. Pp. 23. 1894.

Statement of B. E. Fernow, Chief of Forestry Division, to the Committee on Agriculture, House of Representatives, [in support of H. R. 8389, and H. R. 8390, providing for forestry schools] February 16, 1895. Pp 4.

Senate Document No. 40, Fifty-fifth Congress, first session: White-Pine Timber Supplies. Statement prepared by the chief of the division. Letter of the Secretary of Agriculture. Pp. 21. 1897.

C. FORESTS AND FORESTRY IN THE UNITED STATES.

The following brief account of the forest conditions of the United States; of the trees of economic value which compose its forests; of the materials in kind and quantity which they furnish; and of the status of the movement for the introduction of forestry principles in their use, is brought together mainly from scattered data published by the Division of Forestry and from other sources.

Original Condition of Forest Areas.

The territorial distribution of forest areas in the United States, and indeed on the whole continent, can be divided with more or less precision into three grand divisions:

(1) The Atlantic forest, covering mountains and valleys in the East, reaching westward to the Mississippi River and beyond to the Indian Territory and south into Texas, an area of about 1,361,330 square miles, mostly of mixed growth, hard woods and conifers, with here and there large areas of coniferous growth alone—a vast and continuous forest.

(2) The mountain forest of the West, or Pacific forest, covering the higher elevations below timber line of the Rocky Mountains, Sierra Nevada, and Coast Range, which may be estimated at 181,015 square miles, almost exclusively of coniferous growth, of enormous development on the northern Pacific coast, more or less scattered in the interior and to the south.

(3) The prairies, plains, lower elevations, and valleys of the West, with a scattered tree growth, on which, whether from climatic, geologic, or other causes, forest growth is confined mostly to the river bottoms or other favorable situations, an area of about 1,427,655 square miles, of which 276,965 square miles may be considered under forest cover of deciduous species east of the Rockies and of coniferous and deciduous species in the west of this divide.

Until the present century, in fact until nearly the last half of it, the activity of man on this continent has practically been confined to the eastern portion, which, as stated, was originally covered with a dense or at least continuous forest. The substructure of the entire civilization of the United States was hewn out of these primeval woodlands.

Out of the vast virgin forest area of the eastern half of the country there have been cleared for farm use during this time 250,000,000 acres, or 400,000 square miles, leaving about 961,330 square miles covered actually or nominally with forest growth or waste.

Timber being a great obstacle to the settlement of the land, and the market for it until recently being confined and limited, a large amount had to be wasted and disposed of in the log pile, where the flames made quick work of the scrub as well as of the finest walnut trees.

The settlement of the western mountain country, although emigration to Oregon began in 1842, assumed proportions of practical importance only when the gold fever took many travelers over the plains and mountains to California in 1849 and the following years. If only the legitimate need of the population of this region for cleared land and for timber had made drafts upon the forest resources, the change in forest conditions would have been insignificant, but the recklessness which the carelessness of pioneer life and seemingly inexhaustible resources engender has resulted in the absolute destruction by fire of many thousand square miles of forest growth and the deterioration in quality and future promise of as many thousands more.

The third region, the so-called "treeless area," has experienced, since the advent of the white settlers and the driving out of the Indians, changes which are almost marvelous. The prairies were reached by settlers in any considerable number only as late as the third and fourth decades

of this century, but they and their successors have not only occupied a farm area of 80,000,000 productive acres, but they have also dotted the open country with groves, smaller or larger, either by planting them or, by keeping out fire and cattle, aiding the natural reforestation.

Present Condition.

The requirements of the settlement of agricultural lands, then, have necessitated the removal of the forest from abont 250,000,000 acres. But in addition two other causes—fire and wood consumption—have reduced the really forest-bearing area still further. While the larger amount of wood prodncts is not secured by clearing lands, but mostly by culling the virgin forest of the best kinds and the best individual trees, so that at least a woodgrowth more or less valuable continues to occupy the ground, many of these areas are so severely culled that they are of no economic value. Especially when, as is often the case, fires follow the operations of the lumbermen, not only the old timber and the young growth, but the mold, the fertility of the soil, a product of centuries of decaying vegetation, is also destroyed and the ground is occupied by weeds and useless brush. If left to itself and no fires recurring, these wastes may again become valuable forests, but this recuperation will take generations if not centuries before an economic value attaches to the area. Thus in Wisconsin, as we will see further on, at least 4,000,000 acres have been turned into veritable desert by these processes.

It will be readily understood that if we consider forests from the economic point of view as woodlands either containing or promising for the future wood of useful kinds, not merely tree weeds and brush, we must classify and distinguish with more precision than merely into farm and forest.

The farm areas are ascertained by the census. But of the balance of areas we have no precise knowledge as to its condition, whether virgin and valuable forest growth or a useless and more than useless brush growth occupies them, preventing reestablishment of desirable growth, or whether it is waste, but open country.

Not only should we know the timber areas which contain supplies ready for the ax and for present consumption, but in the so-called second growth we must distinguish the areas which promise new supplies of value and those brush lands which are not only not growing a new timber crop, but, on the contrary, prevent the growth of timber and will for generations to come be mere waste lands.

The census authorities have never had a conception of these differences, hence we are without precise knowledge of the condition of things. It is to be hoped that for the next census, in the year 1900, provision will be made to arrive at this knowledge with some precision, under such a plan as outlined in Bulletin 16 of the Division of Forestry, the results of which for the State of Wisconsin appear at the end of this report.

Meanwhile, a canvass of the available information has enabled the Division of Forestry to estimate the present conditions (1893), as represented by the following tabulation, giving the approximated relation of improved land, forest, and waste land:

Improved and forest land in the United States.

	Area.		Per cent.				
	Total land surface.	Improved land in farms.	Improved land.	Brush, forest, and waste land.	Probably forest.	Brush land.	Open country.
	Acres.	*Acres.*					
United States	1,900,800,000	357,616,000	18	82	26	....	....
Maine	19,132,000	3,044,000	15	85	64	....	....
New Hampshire	5,783,000	1,727,000	29	71	62	....	....
Vermont	5,846,000	2,655,000	45	55	42	....	....
Massachusetts	5,155,000	1,657,000	32	68	29	....	....
Rhode Island	694,000	274,000	39	60	40	....	....
Connecticut	3,100,000	1,379,000	44	55	29	....	....
New England States	39,710,000	10,736,000	27	73	52	....	....
New York	30,376,000	16,389,000	54	46	30	....	....
Pennsylvania	28,790,000	13,210,000	45	65	24	....	....
New Jersey	4,671,000	1,999,000	42	58	41	....	....
Delaware	1,254,000	762,000	60	40	24	....	....
Maryland	6,310,000	3,412,000	54	46	32	....	....
Middle Atlantic States	71,401,000	35,772,000	50	50	28	....	....

Improved and forest land in the United States—Continued.

	Area.		Per cent.				
	Total land surface.	Improved land in farms.	Improved land.	Brush, forest, and waste land.	Probably forest.	Brush land.	Open country.
	Acres.	*Acres.*					
Virginia	25,680,000	9,125,000	35	65	48	....	....
North Carolina	31,089,000	7,828,000	25	75	54	....	....
South Carolina	19,308,000	5,255,000	27	73	45	....	....
Georgia	38,647,000	9,582,000	24	76	50	....	....
Southern Atlantic States	114,724,000	31,790,000	27	73	49	....	....
ATLANTIC COAST	225,835,000	78,298,000	35	65	43	....	....
Florida	34,713,000	1,145,000	3	97	58	....	....
Alabama	32,986,000	7,698,000	23	77	53	....	....
Mississippi	29,658,000	6,849,000	23	77	44	....	....
Louisiana	29,069,000	3,775,000	13	87	45	....	....
Gulf States	126,426,000	19,467,000	16	84	50	....	....
Texas	167,808,000	20,746,000	12	88	23	....	....
Michigan	36,755,000	9,865,000	26	74	50	....	....
Wisconsin	34,848,000	9,793,000	28	72	47	....	....
Minnesota	50,691,000	11,128,000	21	79	36	....	....
Northern lumbering States	122,294,000	30,786,000	25	75	43	....	....
Ohio	26,086,000	18,338,000	71	29	16	....	....
Indiana	22,982,000	15,107,000	65	35	15	....	....
Illinois	35,840,000	25,669,000	71	29	10	....	....
Northern agricultural States	84,908,000	59,114,000	69	31	13	....	....
LAKE STATES	207,202,000	89,900,000	43	57	31	....	....
West Virginia	15,772,000	4,554,000	28	72	52	....	....
Kentucky	25,600,000	11,819,000	46	54	43	....	....
Tennessee	26,720,000	9,362,000	35	65	55	....	....
Arkansas	33,949,000	5,475,000	16	84	60	....	....
Missouri	43,990,000	19,792,000	45	55	36	....	....
Central States	146,031,000	51,002,000	35	65	48	....	....
Iowa	35,504,000	25,429,000	71	29	13	....	....
North Dakota	45,398,000	4,658,000	10	90	1	....	....
South Dakota	49,696,000	6,959,000	14	86	2	....	....
Nebraska	42,998,000	15,247,000	34	65	3	....	....
Kansas	52,288,000	22,303,000	42	58	7	....	....
Oklahoma	24,960,000	564,000	2	98	....	....	....
Prairie States	250,754,000	75,160,000	30	70	4	....	....
INTERIOR STATES	396,785,000	126,162,000	32	68	20	....	....
Montana	92,998,000	915,000	1	99	18	20	61
Wyoming	62,448,000	476,000	0·7	99	12	16	71
Colorado	66,332,000	1,823,000	2·7	97	16	21	60
New Mexico	78,374,000	263,000	0·3	99	6	21	72
Eastern Rocky Mountain region	300,154,000	3,477,000	1	99	13	20	66
Idaho	53,945,000	606,000	1	99	20	40	39
Nevada	70,233,000	723,000	1	99	....	9	90
Utah	52,601,000	548,000	1	99	16	27	56
Arizona	72,268,000	104,000	0·1	99·9	14	12	74
Western Rocky Mountain region	249,047,000	1,981,000	0·7	99·3	8	22	69
ROCKY MOUNTAIN REGION	549,201,000	5,458,000	1	99	10	21	6
California	99,827,000	12,222,000	12	88	18	27	43
Oregon	60,518,000	3,516,000	6	94	34	28	32
Washington	42,703,000	1,820,000	4	96	55	21	20
Pacific coast	203,048,000	17,558,000	8	92	30	27	35

NOTE.—The authority for the area of improved farm land is furnished by the census of 1890. The areas of forest, brush, and waste lands were ascertained by subtracting the area of cultivated land from the total land areas of the several States, and are placed as per cent of the total areas in column 4. The part of these supposed to be forest is estimated on information obtained by various agencies. For the western section of the country the further subdivision into forest, brush, and open country is based partly on statistics gathered by Colonel Ensign and published in Bulletin 2 of the Division of Forestry, and partly on the map republished from the report of the Division for 1892.

These figures would indicate that, in round numbers, less than 350,000,000 acres are turned into farm lands, more than two-thirds of which was hewn out of the forest; that the productive area of forest growth, by no means all virgin, falls somewhat below 500,000,000 acres; that nearly 450,000,000 acres are open country, which is presumably incapable of producing any valuable forest growth on account of climatic deficiencies, leaving a balance of over 600,000,000 acres as waste and brush land, of which at least three-fourths have been made so by the combined efforts of ax and fire.

It will appear astonishing to those who have not paid attention to the question of the settlement of this country to learn from the above table that while of the total country only 18 per cent is improved, and for every acre of farm land in the forested country we have destroyed nearly three acres of forest growth, the better developed eastern part (east of Colorado) shows only 29 per cent improved, and even the long-settled Atlantic coast, which we are apt to consider fully occupied, still possesses 65 per cent of unimproved land, of which we estimate 43 per cent as woodland, while the percentage of woodland for the whole country is 26. There would be woodland enough to satisfy our needs for many decades if attention were but paid to its rational use and to the recuperation of the cut-over areas; but the condition of the wooded areas, which have been culled, is well known to be so poor, as far as market supplies are concerned, that for generations to come they must be left out of consideration.

The accompanying map (Pl. I) shows by various grades of color the approximate relative proportion of forest to total area, and the character of the merchantable kinds of lumber that are derived from the different regions is indicated.

A second map (Pl. II) shows more in detail the condition of that section of the country west of the ninety-seventh degree of longitude, which, being largely situated in the dry region, requires greatest attention to conservative forest use and contains still large areas of public timber lands. The information is derived from members of the United States Geological Survey and others acquainted with the region. It must not be overlooked, however, that these are not accurate surveys, but approximations, and that a large per cent, often from 25 to 50 per cent of the area falling within the timber land or brush-land area, is prairie, open country, waste land, or in cultivation. The location and size of the national forest reservations, first made under the act of March 3, 1891, have also been outlined on this map, suggesting a desirable extension of this policy which has since been had.

The figures and maps show the very uneven distribution of the forest areas, which is an important fact from an economic point of view. Seven-tenths are found on the Atlantic side of the continent, only one-tenth on the Pacific coast, another tenth on the Rocky Mountains, the balance being scattered over the interior of the Western States.

Both the New England States and the Southern States have still 50 per cent of their area, more or less, under forest cover, but in the former the merchantable timber has been largely removed.

The prairie States, with an area in round numbers of 400,000 square miles, contain hardly 4 per cent of forest growth, and the 1,330,000 square miles—more than one-third of the whole country—of arid or semiarid character in the interior contain practically no forest growth, economically speaking.

The character of the forest growth also varies in the different regions, as we will presently see more in detail. On the Pacific coast, hard woods are rare, the principal growth being coniferous and of extraordinary development. Besides gigantic redwoods, the soft sugar pine and the hard bull pine, various spruces and firs, cedars, hemlocks, and larch form the valuable supplies.

In the Rocky Mountains no hard woods of commercial value occur, the growth being mainly of spruces, firs, and bull pine, with other pines and cedars of more or less value.

The Southern States contain in their more southern section large areas occupied almost exclusively by pine forests, with the cypress in the bottom lands; the more northern portions are covered with hard woods almost exclusively, and intervening is a region of mixed hard-wood and coniferous growth. Spruces, firs, and hemlocks are found in small quantities confined to the mountain regions.

The Northern States are mainly occupied by hard-wood growths, with conifers intermixed, sometimes the latter becoming entirely dominant, as in the spruce forests of Maine, New Hampshire, or the Adirondacks, and here and there in the pineries of Michigan, Wisconsin, and Minnesota, or in the hemlock regions of Pennsylvania and New York.

Forest Botanical Description.

As stated before, we may divide the North American forest according to its botanical features into two great forest regions, namely, the Atlantic, which is in the main characterized by broad-leaved trees, and the Pacific, which is made up almost wholly of coniferous species. (See Pl. III.)

In the Atlantic forest, going from the south to the north, we can again discern several floral

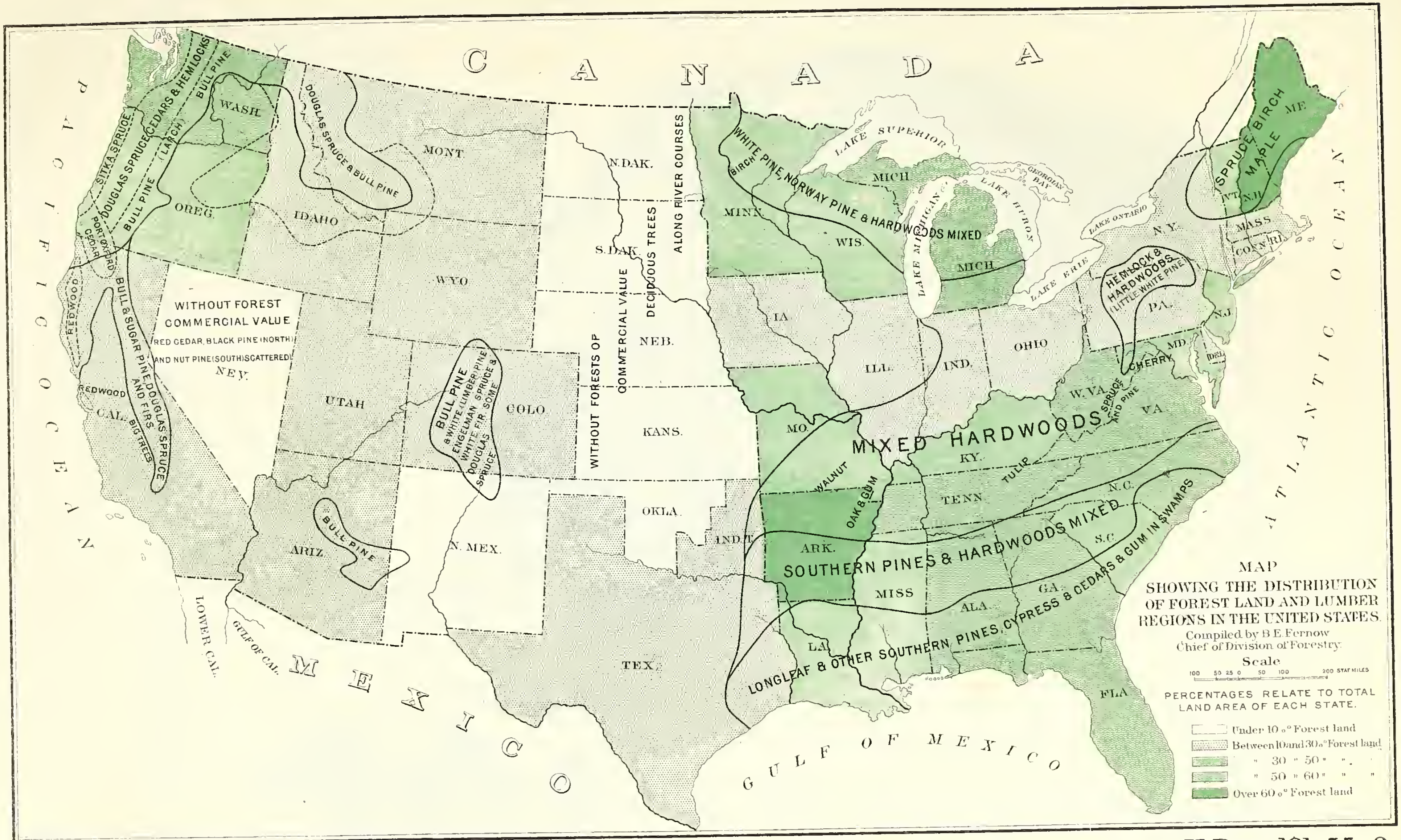

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PLATE II.

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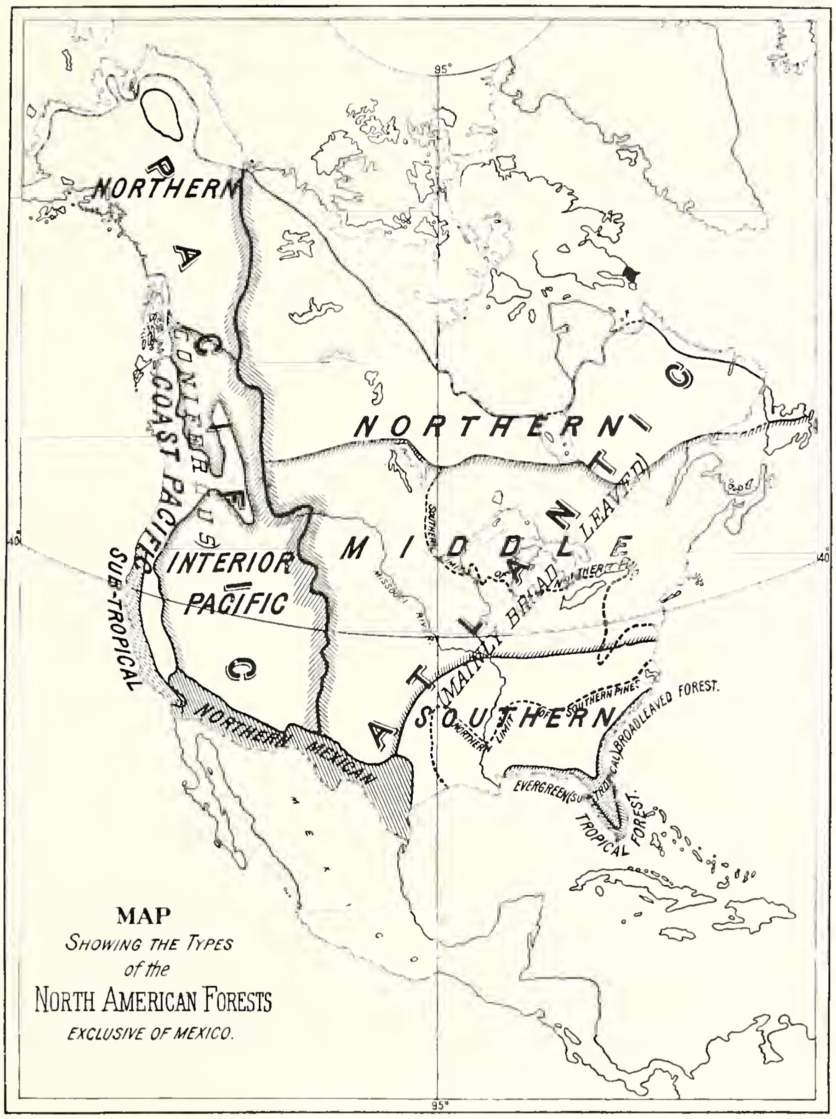

NORTHERN
PACIFIC
COAST PACIFIC
INTERIOR PACIFIC
SUB-TROPICAL
NORTHERN MEXICAN
NORTHERN
MIDDLE
ATLANTIC
MAINLY BROADLEAVED
SOUTHERN
NORTHERN LIMIT OF SOUTHERN PINES
BROADLEAVED FOREST.
EVERGREEN(SUB-TROPICAL)
TROPICAL FOREST.
MISSOURI RIVER
MEXICO
95°
40
140
MAP
SHOWING THE TYPES
of the
NORTH AMERICAN FORESTS
EXCLUSIVE OF MEXICO.

subdivisions, each of which shows special characteristics. The southernmost coast and keys of Florida, although several degrees north of the geographical limit of the Tropics, present a truly tropical forest, rich in the species of the West Indian flora, which here finds a most northern extension. There is no good reason for calling this outpost semitropical, as is done on Professor Sargent's map in the work for the Tenth Census. With the mahogany, the mastic, the royal palm, the mangrove, the sea grape and some sixty more West India species represented, it is tropical in all but its geographical position. That the northern flora joins the tropic forest here, and thus brings together on this insignificant spot some hundred species, nearly one-quarter of all the species found in the Atlantic forest, does not detract from its tropical character.

On the other hand, we may speak with good reason of a subtropical forest north of this region; for here, where the live oak and water oak, the magnolias, the bay tree, and holly, and many other broad-leaved trees, mixed with the sabal and dwarf palmetto, retain their green foliage all through winter, we are forcibly impressed with the semitropic character of this region, which, under the influence of the Gulf stream, extends in a narrow belt of some 20 or 25 miles width along the the coast as far north as North Carolina.

While this evergreen broad-leaved forest is more or less confined to the rich hammocks and moister situations, the poor sand soils of this as well as of the more northern region are occupied by pines; and as these, especially the long-leaf pine, are celebrated all over the world and give the great mercantile significance to these forests, we may well speak of this region from an economic point of view as the "great southern pine belt." North of the "winter-green," subtropic forest stretches the vast deciduous-leaved forest of the Atlantic, nowhere equaled in the temperate regions of the world in extent and perfection of form, and hardly in the number of species. This designation applies to the entire area up to the northern forest belt, for again the region formerly segregated on the census map as the northern pine belt is still in the main the dominion of the deciduous-leaved forest, with the pines, and in some parts spruces, intermixed, or on certain soils, especially on the gravelly drifts and drier sands, become gregarious, even to the exclusion of other species, as on the pine barrens of northern Michigan and the pineries of Wisconsin and Minnesota, which are occupied by two or three species of pine exclusively (white pine, red pine, jack pine). This deciduous-leaved forest may, however, be divided by a line running somewhere below the fortieth degree of latitude, where, with the northern limits of the southern magnolias and other species, we may locate in general the northern limit of the southern forest flora. Northward from here, in what we may call the "Middle Atlantic forest," the deciduous species become less numerous and coniferous growth becomes soon more so, until we arrive at the broad belt of the northern forest, which, crossing from the Atlantic to the Pacific, composed of only 8 hardy species, takes its stand against the frigid breath and icy hands of Boreas.

Abounding in streams, lakes, and swampy areas, the low divides of this region are occupied by an open stunted forest of black and white spruce, while the bottoms are held by balsam firs, larch or tamarack, poplars, dwarf birches, and willows. The white spruce, paper or canoe birch, balsam, poplar, and aspen find congenial conditions, from the Atlantic to the Pacific, over the whole continent.

On the Pacific side the subdivisions of the coniferous forest are rather ranked from west to east. The Pacific interior forest on the Rocky Mountains is wrestling with the droughty atmosphere of the plains and Interior Basin.

Here on the driest parts, where the sage brush finds its home, the ponderous bull pine is the foremost tree, and where even this hardy tree can not succeed in the Interior Basin an eastern ally, the red cedar (now differentiated into different species), holds the fort in company with the nut pine, small and stunted, covering with an open growth the mesas and lower mountain slopes. On the higher and therefore moister and cooler elevations, and especially northern and northwestern exposures, and in the narrow canyons where evaporation is diminished and the soil is fresher, the somber Douglas, Engelmann, and blue spruces and the silver-foliaged white fir join the pines or take their place.

With few exceptions the same species, only of better development, are found in the second parallel which occupies the western slopes of the Sierra Nevada. Additional forces here strengthen the ranks; the great sugar pine, two noble firs, a mighty larch, hemlocks and cedars, arborvitæs, and the big sequoias. The third parallel, the forest of the Coast Range, the most wonderfully

developed although far from being the most varied of this continent, is characterized by the redwood, the tideland or Sitka spruce, hemlock, and giant arborvitæ.

Broad-leaved trees are not absent, but so little developed in comparison with the mighty conifers that they play no conspicuous part except along the river bottoms, where maples, cottonwood, ash, and alder thrive, and in the narrow interior valleys and slopes an open growth of oak is found. Toward the south and on the lower levels the broad-leaved trees again become evergreen as on the Atlantic side, and with a new tribe of pines, with large hooked cones added, form a subtropic flora.

Finally to the south, analogously to the extension of the tropical West Indian flora in Florida, we find a northern extension of the Mexican forest, mingled with which species from the Pacific forest on the west and from the Atlantic on the east. The mesquite and some acacias, the tree yuccas, and the giant or tree cactus are perhaps the most characteristic and remarkable species of the deserts of this region, while the high mountains support dense forests of firs and pines.

This distribution of forest types is exhibited on the accompanying map. Besides the botanical and geographical interest it has an eminently practical interest to the forester, because it shows him the limits within which he may expect to produce satisfactory results with the species of trees composing the forest in each section.

While a vast territory on the Atlantic side and a narrower belt on the Pacific coast, connected by a broad belt through the northern latitudes, bears the forest growth thus differentiated, with the crest and slopes of the Rocky Mountains forming an intermediate extension from the Northern belt, there is a vast empire in the interior without forest growth, although not entirely without tree growth, the prairies and plains.

Of parts of this territory we feel reasonably certain from strong evidences that the forest once occupied them, but has been driven off by aboriginal man, the firebrand taking sides with the grasses, and the buffalo probably being a potent element in preventing reestablishment. In other parts it is questionable whether the lines along the river courses, the straggling trees on the plateaus and slopes, are remnants of a vanquished army or outposts of an advancing one. In some parts, like the dry mesas, plateaus, and arroyos of the interior basin, and the desert-like valleys toward the southern frontiers, it may reasonably be doubted whether arborescent flora has more than begun its slow advance from the outskirts of the established territory.

Certain it is that climatic conditions in these forestless regions are most unfavorable to tree growth, and it may well be questioned whether in some parts the odds are not entirely against the progress of the forest.

Temperature and moisture conditions of air and soil determine ultimately the character of vegetation, and these are dependent not only on latitude, but largely on configuration of the land, and especially on the direction of moisture-bearing winds with reference to the trend of mountains.

The winds from the Pacific Ocean striking against the Coast Range are forced by the compression and subsequent cooling to give up much of their moisture on the windward side; a second impact and further condensation of the moisture takes place on the Cascade Range and Sierra Nevada. On descending, with consequent expansion, the wind becomes warmer and drier, so that the interior basin, without additional sources of moisture and no additional cause for condensation, is left without much rainfall and with a very low relative humidity, namely, below 50 per cent. The Rocky Mountains finally squeeze out whatever moisture remains in the air currents, which arrive proportionally drier on the eastern slope. This dry condition extends over the plains until the moist currents from the Gulf of Mexico modify it. Somewhat corresponding, yet not quite, to this distribution of moisture, the western slopes are found to be better wooded than the eastern, and the greater difficulty of establishing a forest cover here must be admitted; yet since the forest has the capacity of creating its own conditions of existence by increasing the most important factor of its life, the relative humidity, the extension of the same may only be a question of time.

Temperature extremes, to be sure, also set a limit to tree growth, and hence the so-called timber line of high mountains, which changes in altitude according to the latitude.

If, now, we turn our attention from the phyto-geographic consideration of the forest cover to the botanical features, we may claim that the North American forest, with 450 or more arborescent species, belonging to 158 genera, many of which are truly endemic, surpasses in variety of useful species and magnificent development any other forest of the temperate zone, Japan hardly excepted.

In addition there are probably nowhere to be seen such extensive fields of distribution of single species.

These two facts are probably explained by the north-and-south direction of the mountain ranges, which permitted a reestablishment after the Ice age of many species farther northward, while in Europe and the main part of Asia the east-west direction of the mountains offered an effectual barrier to such reestablishment, and reduced the number of species and their field of distribution; nor are the climatic differences of different latitudes in North America as great as in Europe, which again predicates greater extent in the fields of distribution north and south. On the other hand, the differences east and west in floral composition of the American forest are greater than if an ocean had separated the two parts instead of the prairie and plains. This fact would militate against our theory that the intermediate forestless region was or would be eventually forested with species from both the established forest regions, if we did not find some species represented in both regions and a junction of the two floras in the very region of the forestless areas. In the sand hills which traverse Nebraska from east to west there are now found in eastern counties the sand-drowned trunks of the western bull pine, and the same pine belonging to the Pacific flora is found associated with the black walnut of the eastern region along the Niobrara River.

Of the many species which in each of the forest regions compose the forest, only a limited number can be classed as economically valuable, although the question as to what is valuable is not one readily answered, since many trees which appeared valueless at first have proved their usefulness when better known or when the more serviceable timbers became scarcer. The trade papers quote at best only 35 to 40 kinds, of which only 10 to 12 are regular staples. In addition, some species possess value to the forester in his silvicultural operations, as nurses, soil cover, etc., which to the wood consumer appear only as tree-weeds. Finally, some species, like the lodgepole pine of the Northern Rocky Mountains, are most valuable from the national economic point of view, because covering large areas of mountain slopes, thereby not only furnishing wood supplies, albeit of an inferior character, to the resident population, but covering the watersheds and favorably influencing soil and water conditions.

The selection of species to be considered economically valuable, therefore, must be, to some extent, arbitrary, and be guided by a variety of considerations in which those of the present may vary from those of the future. The relative value of those selected may also change from time to time and from locality to locality.

Thus for the present we can dismiss from consideration the 60 to 70 species of tropical origin, importations from the West Indies, found along the coast and keys of Florida in small quantities, as economically of little consequence on account of the small area which they do and can occupy.

Another similar exclusion may be made of some species which overlap from the Mexican flora, some 26 or 27, with but a confined distribution in the United States. There remain then about 360 species which call for a discriminating classification, and if we exclude all species which, as a rule, do not exceed 1 foot in diameter, we decrease this number again to, say, 235 species, which, possibly, may enter into the consideration of forest management and are of economic value.

A full checklist of the entire arborescent flora is to be found (besides the magnificent work, the Silva, by Prof. C. S. Sargent, which describes this flora fully by word and picture) in Bulletin 14 of the Division of Forestry, and a more condensed statement in Bulletin 18. For the present report, which is to consider economic questions mainly, the list given in the next few pages, being reproduced from the Annual Report of the Division for 1886, somewhat revised, may suffice.

Trees of the United States Important in Forestry.

[The relative value of the different species here enumerated is indicated in three classes by difference in type, as follows: First grade, **WHITE PINE**; second grade, JEFFREY PINE; third grade, *PITCH PINE*.

The size stated refers to averages of mature trees; the + sign denoting that larger dimensions are not uncommon.]

A. CONIFERS.

(Evergreen and needle-leafed trees, with a few exceptions.)

The most valuable forest trees, as well on account of their usefulness as for their effects in forestry, due to the evergreen foliage of most of them persistent through several years; most capable of covering extensive areas exclusively, and with deciduous trees most excellent aids in forestry on account of their habit of growth and their soil-

improving qualities; practically not capable of reproduction by sprouting from the stocks or cuttings; mostly periodical seeders; persistent growers.

PINES.—The most useful conifers and most important forest trees, mostly of the plain; reaching desirable development in comparatively dry, even barren, situations. Mostly needing light; tolerably rapid growers; best on light sandy soils with clay subsoil.

Characteristics.—Leaves arranged in twos, threes, or fives in one sheath; cones with thickened scales; seeds almond-shaped, nut-like, of mottled appearance, with their wings only lightly attached; maturing the second year, and preserving their germinating power well. Sixty to seventy species, of which thirty-five are indigenous to the United States.

Wood.—Very variable, very light and soft in "soft" pine, such as white pine; of medium weight to heavy and quite hard in "hard" pine, of which Longleaf or Georgia pine is the extreme form. Usually it is stiff, quite strong, of even texture, and more or less resinous. The sapwood is yellowish-white; the heartwood, orange-brown. Pine shrinks moderately, seasons rapidly and without much injury; it works easily; is never too hard to nail (unlike oak or hickory); it is mostly quite durable, and if well seasoned is not subject to the attacks of boring insects. The heavier the wood, the darker, stronger, and harder it is, and the more it shrinks and checks. Pine is used more extensively than any other kind of wood. It is the principal wood in common carpentry, as well as in all heavy construction, bridges, trestles, etc. It is also used in almost every other wood industry, for spars, masts, planks, and timbers in shipbuilding, in car and wagon construction, in cooperage, for crates and boxes, in furniture work, for toys and patterns, railway ties, water pipes, excelsior, etc. Pines are usually large trees with few branches, the straight, cylindrical, useful stem forming by far the greatest part of the tree; they occur in vast forests, a fact which greatly facilitates their utilization.

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and uses of their wood.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
1. **WHITE PINE**	Northern; wide range, forming forests to Southern mountains.	Best on light, sandy, fresh, deep soil, but successful on a large range of soils from dry to moist. Rapid grower; endures some shade; hardy, but little tolerant of drought.
(*Pinus strobus* Linn.) Height, 120 feet +; diameter, 3 feet +.	Best development in region of the Great Lakes.	The *most important* conifer of the United States; good quality, however, only in centenarians. Is best mixed with deciduous trees; of rather slow, but high percentage of germination; plant one or two-year-old transplanted seedlings, or sow.
2. **RED PINE** (NORWAY PINE.)	Northern; associated mostly with White Pine.	Soils like those of White Pine; adapted to many soils, but best quality of timber produced in well-drained sands. Extremely hardy; *vigorous* and *rapid* grower.
(*Pinus resinosa* Ait.) Height, 100 feet +; diameter, 2½ feet +.	Greatest development from Michigan to Minnesota.	Should be favored in northern and northeastern planting with White Pine and deciduous trees. So far, seed very expensive and difficult to obtain.
3. *PITCH PINE* (*Pinus rigida* Miller.)	Northeastern and Middle Atlantic States.	Best on fresh to moist sand, but will succeed on dry, barren, sandy, or rocky soils, and even on wet, cold, swampy ground, or seacoasts liable to floods.
Height, 50 feet +; diameter, 1½ feet +.		A rapid grower, and when young hardy and indifferent to drought; light-needing; an early seeder; sprouts from the stump; not easily transplanted; best and *easily* propagated from *seed;* mainly for *seacoast* planting.
4. *JACK PINE*	Northern (in United States), forming forests far north.	Common on sandy, barren soil.
(SCRUB PINE. PRINCE'S PINE.) (*Pinus divaricata* (Ait.) Gord.) Height, 60 feet +; diameter, 1 foot +.	Greatest development north of Lake Superior.	Valuable only as first cover for northern pine-barrens. Rapid grower in its youth and easily handled; very hardy, enduring heat and cold well; successful on the plains.
5. *SCRUB PINE* (*Pinus virginiana* Mill.) Height, 80 feet +; diameter, 2 feet +.	Middle Atlantic region	Common on poor, dry, sandy, gravelly, and clayey soils; less frequent in rich soils. Moderately rapid grower, quickly taking possession of old, worn-out fields and washed lands.
6. **LONGLEAF PINE**	South Atlantic and Gulf States	Well drained, loose, deep sandy loam or gravel.
(SOUTHERN PINE. YELLOW PINE. GEORGIA PINE. HARD PINE.)		The slow growth of first five years (quasi-endogenous) makes its forestry problematic; development dependent on atmospheric moisture; least shade-enduring of pines.
(*Pinus palustris* Miller.)		Rare, but plentiful seeder; germinates freely; can therefore be propagated by sowing seed in permanent place.
Height, 100 feet +; diameter, 2½ feet +.		Most valuable pine of the South, but for best quality requires long period of growth (two hundred years?).
7. **SHORTLEAF PINE**	Middle Atlantic and Southern States; associated mostly with hardwood trees.	More common on light sandy soil than on low borders of swamps.
(BULL PINE. YELLOW PINE. SPRUCE PINE.) (*Pinus echinata* Miller.) Height, 90 feet +; diameter, 2 feet +.	Best development in western Louisiana, southern Arkansas, and eastern Texas.	A rather slow grower; will succeed on the poorest soil. Easily reproduced; good seeder; light-needing.

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and uses of their wood—Continued.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
8. **CUBAN PINE** (SPLASH PINE. SWAMP PINE. BASTARD PINE.) (*Pinus heterophylla* (Ell.) Sudw.) Height, 90 feet +; diameter, 2 feet +.	Southern and southeastern coast; local in swamps and near water courses. Best development in eastern Florida.	Light sandy soil; somewhat indifferent to drainage. *Rapid grower,; easily reproduced;* matures seed yearly; competing with the Longleaf Pine on wet sags; light-needing.
9. **LOBLOLLY PINE** (OLD-FIELD PINE.) (*Pinus tæda* Linn.) Height, 100 feet +; diameter, 2½ feet +.	Southeastern Greatest development in Virginia and North Carolina.	Low, moist, or dry sandy soils and abandoned fields. Adapted to a wide range of sites. Rapid grower; *light-needing;* seeds persistently and plentifully. A useful concomitant of Southern forestry.
10. *SPRUCE PINE* (OLD-FIELD PINE OF FLORIDA. CEDAR PINE. WHITE PINE.) (*Pinus glabra* Walter.) Height, 80 feet +; diameter, 2 feet +.	Southeastern States Best development in Alabama and Mississippi.	Grows on better and moister soils than *Pinus tæda*, especially on hummocks and rich bottom lands; rare; usually isolated or in groups. A rapid grower; shade-enduring.
11. **BULL PINE** (YELLOW PINE. HEAVY-WOODED PINE.) (*Pinus ponderosa* Douglas.) Height, 200 feet +; diameter, 12 feet +.	Rocky Mountains to the Pacific, up to high elevations; forming forests. Best developed on western slope of Sierras of northern and central California.	Dry rocky ridges and prairies, sometimes in swamps; but best in deep loamy sand. Vigorous, rapid grower; very hardy, except when quite young. Well adapted to dry, windy, exposed places; succeeds on Western prairies. The pine for reforesting southern exposures of the Western mountain regions.
12. *BRISTLE-CONE PINE* (*Pinus aristata* Engelm.) Height, 100 feet; diameter, 4 feet.	Local—Rocky Mountains and southeastern California; above 7,500 feet.	Dry, gravelly ridges. The White Pine for cover of high elevations in southern Rocky Mountains.
13. **SUGAR PINE** (*Pinus lambertiana* Dougl.) Height, 150 feet +; diameter, 4 feet +.	Western Pacific slope Best development in Sierras of central and northern California above 4,000 feet; lower in Oregon.	Very rapid grower. Quite hardy in the East. Best Pine for reforestation in its native habitat.
14. SILVER PINE (MOUNTAIN PINE. LITTLE SUGAR PINE.) (*Pinus monticola.*) Height, 100 feet +; diameter, 4 feet +.	Northern Rocky Mountains and Western Pacific slope. Best development numerically in northern Idaho.	Similar to Sugar Pine, which it accompanies on the Pacific slope.
15. *MONTEREY PINE* (*Pinus radiata* Don.) Height, 80 feet +; diameter, 2 feet +.	Local—California coast, south of San Francisco.	Light, well-drained soils, and on drifting sands. Easily propagated; seed of very high percentage of germination; very rapid grower. Useful for reforesting Western barrens.

II. SPRUCES.—Next in importance to the pines, though the wood is less resinous, weaker, and not so durable. Of northern or mountain habitat, in cool situations and moist soils; endures shade, and grows mostly with rapidity and persistency. The Norway Spruce of Europe appears, so far, superior for forestry to the native species.

Characteristics.—Leaves single, rigid, sharp-pointed, four-cornered, bristling mostly all around the twigs; cones oblong, hanging, with thin, persistent scales; seeds resembling those of the pines, but usually smaller, more uniform in color, and angular; mature the first year, and preserve power of germination well; mostly periodical, but seeds abundantly; crown pyramidal; about twelve species, of which five are indigenous. Spruce wood resembles soft pine, is light, soft, stiff, moderately strong, less resinous than pine; has no distinct heartwood, and is of whitish color; used like soft pine, but also employed as resonance wood, and preferred for paper pulp. Spruces, like pines, form extensive forests. They are more frugal, thrive on thinner soils, and bear more shade, but usually require a more humid climate. "Black" and "white" spruce, as applied by lumbermen, usually refer to narrow and wide ringed forms of the Black Spruce (*Picea mariana*).

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and uses of their wood—Continued.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
16. BLACK SPRUCE[1]	Mainly northeastern; forming forests.	Light, dry, stony soils; much smaller in cold, wet swamps.
(*Picea mariana* (Mill.) B. S. P.)	Best development north of latitude 50°.	Rapid grower.
Height, 80 feet; diameter, 1½ feet +.		
17. WHITE SPRUCE (*Picea canadensis* (Mill.) B. S. P.) Height, 100 feet; diameter, 1½ feet +.	Mainly northeastern and extending into Rocky Mountains; forming forests.	Like Black Spruce, but probably better adapted to western planting, being hardier.
18. ENGELMANN SPRUCE (WHITE SPRUCE.)	Western mountain regions and northward; high elevation.	Dry, gravelly slopes, 5,000 to 11,500 feet.
(*Picea engelmanni* Engelm.) Height, 100 feet +; diameter, 3 feet +.	Best development in central Rocky Mountain region, between 9,000 and 10.000 feet.	A tree for reforestation of mountain slopes along water courses.
19. SITKA SPRUCE (TIDE-LAND SPRUCE.)	Alaska and Northwestern coast; low elevations.	Moist soil and climate, at least a moist subsoil, shady situations. *Rapid grower.*
(*Picea sitchensis* Carrière.) Height, 150 feet +; diameter, 6 feet +.		Probably hardy in Northeastern and Middle States, in shaded positions.

[1] Includes also the Red Spruce (*Picea rubra*), this being the principal timber spruce of the region.

III. FIRS.—Important to forestry mainly on account of their great endurance of shade. Of northern and mountain distribution; still more dependent on moisture of climate and cool or at least evenly tempered situations than the spruces, and in their youth mostly less hardy; usually grow slowly, but persistently. Some exotics seem to be of more value than the native species (*Abies nordmanniana*).

Characteristics.—Leaves single, flat, rather blunt, arranged somewhat comb-like on the twigs. Cones cylindrical, standing erect on the branches; scales thin, and falling away when mature; seeds triangular, partly inclosed by a more or less persistent wing; mature first year, but do not preserve their power of germination well. Frequent and abundant seeders. Crown conical. About eighteen species, of which eight are indigenous.

The name is frequently applied to wood and to trees which are not fir; most commonly to spruce, but also, especially in English markets, to pine. The wood resembles spruce in color, quality, and uses, but is easily distinguished from it, as well as from pine and larch, by the absence of resin ducts.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
20. WHITE FIR (BALSAM FIR. BLACK BALSAM.)	Southwestern mountains and Pacific slope; high elevations.	Moist slopes and canyons, between 3,000 and 9,000 feet; cool and shady situations.
(*Abies concolor* (Gord.) Parry.) Height, 100 feet +; diameter, 4 feet +.	Best development in Sierras of California.	
21. *BALSAM FIR*	Northeastern States and northward.	Cold, damp woods and swamps.
(BALM OF GILEAD FIR.) (*Abies balsamea* Miller.) Height, 70 feet +; diameter, 1½ feet +.		Rapid grower. Valuable only as undergrowth or as nurse, and in imperfectly drained situations.
22. GREAT SILVER FIR	Northwestern coast	Bottom lands; rich, moist soil.
(WHITE FIR.) (*Abies grandis* Lindl.) Height, 200 feet; diameter, 5 feet +.	Best development in western Washington and Oregon, along river bottoms.	Very hardy and rapid grower; affected less by late frosts and occasional droughts than most firs.
23. NOBLE FIR (*Abies nobilis* Lindl.) Height, 200 feet +; diameter, 5 feet +.	Northwestern coast; wide range; always near mountain tops and high elevations; found often in groves dispersed through extensive forrests.	Probably hardy east of the Rocky Mountains, with proper protection.
	Best development in Sierra Nevada, from Columbia River to northern California.	Requiring moist atmosphere for best development.

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and uses of their wood—Continued.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
24. AMABILIS FIR...................	Northwestern coast, mostly associated with the preceding species.	Gravelly soils.
(*Abies amabilis* (Loud.) Forbes.)		
Height, 100 feet +; diameter, 4 feet +. According to others, 250 feet high and 5 feet in diameter.	Best development on mountains south of the Columbia River; 3,000 to 4,000 feet.	Will probably prove hardy in Eastern States.

IV. BASTARD SPRUCES.—Under this name may be grouped the Hemlocks and Douglas Spruce, formerly classed with the spruces and firs proper. Mostly of northern distribution, and therefore best adapted to cool, moist situations; enduring considerable shade. Some of the species grow very rapidly.

Characteristics.—Leaves single, flat, linear, with distinct stalks (petioles) somewhat comb-like in their arrangement on the twigs. Cones usually small, with thin scales, hanging from the ends of the branches. Seeds partly inclosed in a persistent wing; resemble those of the firs, but of smaller size; mature the first year; do not keep well; low percentage of germination. Branches pendant; crown spindle-like in form. Two genera, comprising seven species, five of which are indigenous.

The wood of the Douglas Spruce resembles the common "hard pine" (Red, Loblolly, etc.) in texture and grain, resembles the larch in color, and is used for all purposes for which pine is employed, the excellent dimensions naturally leading to its preference for many purposes.

The wood of the Eastern Hemlock is used chiefly for dimension stuff, also for boards, and recently for pulp; but it has been well demonstrated that the wood is well suited even for finishing lumber, and that the prevailing prejudice against it is as unwarranted in the case of the Eastern as in that of the Western Hemlock. The appearance of the wood in oil finish is very satisfactory.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
25. **DOUGLAS SPRUCE**.......	Rocky Mountain region to Pacific; wide range; forming forests.	Accommodates itself to many soils, but prefers a deep and moist cool and well-drained one; succeeds well on a dry, slaty soil, and on sand dunes and exposed situations.
(RED FIR. YELLOW FIR. OREGON PINE.)		
(*Pseudotsuga taxifolia* (Poir.) Britt.)	Best development in Western Oregon and Washington.	Surpasses almost all of the conifers in the *rapidity* of its growth, and endures *drought* better than most of them; *shade-enduring*.
Height, 300 feet +; diameter, 10 feet +.		One of the largest and most important forest trees of the West. For Eastern planting seed should be procured from Colorado or Montana. Repairs damage very readily.
26. HEMLOCK.........................	Northern and Eastern States, forming forests.	Light, alluvial loam, well-drained, but cool and moist situations.
(*Tsuga canadensis* (Linn.) Carr.)		
Height, 80 feet +; diameter, 3 feet +.	Best development probably in Canada.	Grows slowly when young, but tolerably rapidly after four or five years; endures shade.
		Excellent nurse tree for White Pine, with which it is usually associated.
27. WESTERN HEMLOCK..........	Northwestern States, between 1,000 and 4,000 feet.	A substitute for the above species on the Pacific coast.
(*Tsuga mertensiana* (Bong.) Carr.)		An exceedingly rapid grower, even on poor soils.
Height, 180 feet +; diameter, 6 feet +.	Best development in western Oregon and Washington.	Very shade-enduring, forming large part of the undergrowth in its habitat.

V. DECIDUOUS CONIFERS.—Though botanically not classed together, yet in forestry they may be considered allied, as the yearly fall of leaves improves the soil, while the absence of foliage during the winter and early spring distinguishes them from the evergreens, and their extreme need of light requires similar forest management. The Larches are of Northern or mountain habitat and the Bald Cypress of local southern distribution; but are all adapted to various situations. The European Larch probably surpasses the Northeastern Tamarack in every respect.

Characteristics.—Larches: Leaves in clusters, slender, and soft. Cones small, egg-shaped, or elongated, with thin scales. Seeds small, triangular, nut-like in shape; mature the first year. Produces seed frequently and abundantly. Seeds keep well, but are of low percentage of germination.

Bald Cypress: Leaves single, sharp-pointed, very small and scanty, comb-like in the arrangement on the young twigs. Cones ball-like, with thick, woody scales, falling apart when mature. Seeds irregularly triangular-shaped, with hard, thick, wood-like shell; mature yearly abundantly, and keep well.

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and use of their wood—Continued.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
28. **BALD CYPRESS** (*Taxodium distichum* Rich.) Height, 150 feet; diameter, 8 feet.	South Atlantic and Gulf States, forming forests in swamps and pine-barren ponds.	Indifferent to imperfect drainage and flooding, but capable of rapid growth on well-drained, moist, sandy soils, and hardy as far north as latitude 39° and 40°, and even on Western prairies. Positively light-needing. To be recommended for extensive planting in favorable situations, where even, superior lumber may be expected.
29. *TAMARACK* (BLACK LARCH. HACKMATACK.) (*Larix laricina* (Du Roi) Koch.) Height, 80 feet; diameter, 1 foot +.	Northeastern (in United States)... Best development probably north of the United States boundary.	North of United States boundary, found on moist uplands; south in United States, in cold, wet swamps; but probably of more value when grown on deep, moist, well-drained soils, in cool situations. Rapid and persistent grower; light-needing. Deserves attention in Northern forestry, but only in mixed growths.
30. **WESTERN LARCH** (TAMARACK.) (*Larix occidentalis* Nutt.) Height, 100 feet +; diameter, 4 feet +.	Northwestern; elevations between 2,500 and 5,000 feet. Best development in valley of Flathead River, Montana.	An important tree as a Western representative of the foregoing species, occupying dry slopes in dry climate.

VI. CYPRESS FAMILY.—Under this head may well be grouped the junipers and so-called cedars, to which can be added the California redwoods. Characterized mostly by the shingle-like arrangement of their small, scaly leaves, the small, roundish fruit (a cone, or berry-like), and by the usually upright habit of the branches and scanty fall of leaves.

Their great endurance of shade makes them valuable adjuncts to forestry; otherwise of only secondary importance. Of the many species contained in seven genera, but fourteen are found in the United States.

Wood light, soft, stiff, not strong, of fine texture; sap and heartwood distinct, the former lighter, the latter a dull, grayish brown, or red. The wood seasons rapidly, shrinks and checks but little, and is very durable. Used like soft pine, but owing to its great durability preferred for shingles, etc. Small sizes used for posts, ties, etc. Cedars usually occur scattered, but they form in certain localities forests of considerable extent.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
31. **RED JUNIPER** (SAVIN.) (*Juniperus virginiana* Linn.) Height, 50 feet +; diameter, 1½ feet +.	Eastern United States. Best development in valley of Red River, Texas.	Prefers a mild climate; deep swamps, borders of streams, ridges, hills; will thrive on a rather dry, loose soil. Easily propagated from seed and cuttings. Perhaps the most important conifer for Southwestern prairie planting, enduring drought and partial shade. Tolerably rapid grower.
32. WHITE CEDAR (*Chamæcyparis thyoides* (Linn.), B. S. P.) Height, 70 feet +; diameter, 1½ feet +.	Atlantic and Gulf States to central Mississippi. Most abundant and best developed in Virginia and North Carolina.	Always in low, marshy, or wet ground, where it thrives well and grows rapidly. Endures moist, upland soils, but with slow growth. Very shade-enduring; easy to propagate from seed or cuttings.
33. PORT ORFORD CEDAR (*Chamæcyparis lawsoniana* (Murr.) Parl.) Height, 150 feet +; diameter, 8 feet +.	Small range; in Oregon along western coast from Coos Bay, Oregon, to Crescent City, Cal.	Commonly in low, moist, rich soil. Apparently hardy in the Northeastern States and succeeds on deep, rich, upland soils and maintains itself in clay loam.
34. **YELLOW CEDAR** (*Chamæcyparis nootkatensis* (Lamb.) Spach.) Height, 150 feet +; diameter, 5 feet +.	Northwest coast region, from Mt. Jefferson northward. Most common on the seacoast north of United States boundary.	Like Arbor Vitæ.
35. *ARBOR VITÆ* (WHITE CEDAR.) (*Thuja occidentalis* Linn.) Height, 50 feet +; diameter, 1½ feet.	Northeastern States and northward.	Will grow well in any soil not too stiff; often forming dense, pure growths in wet, boggy swamps. Rapid grower; easily propagated; desirable for undergrowth and to fill out places where other trees fail to come.
36. GIANT ARBOR VITÆ (RED CEDAR. YELLOW CEDAR.) (*Thuja plicata* Don.) Height, 150 feet +; diameter, 9 feet +.	Northwestern coast and from Humboldt, Cal., to British Columbia. Best development north of Seattle.	Like the above species, on Pacific coast.

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and use of their wood—Continued.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
37. INCENSE CEDAR (BASTARD CEDAR. POST CEDAR. INCENSE CEDAR.) (*Libocedrus decurrens* Torr.) Height, 100 feet +; diameter, 6 feet +.	In interior valley between Coast Range and Sierra from middle Oregon to California (between 3,000 and 8,500).	Slopes and valleys, in well-drained and dry soils. Rapid grower; of excellent appearance. In the East probably adapted only to Southern States; succeeds excellently at Washington, D. C.
38. **REDWOOD** (*Sequoia sempervirens* Endl.) Height, 300 feet +; diameter, 20 feet +.	California coast from Oregon southward; forest-forming.	Low, moist, well-drained situations and damp climate; not on dry hillsides. Vigorous and persistent grower; shade-enduring; sprouts from the stump. Highly important for California forestry; perhaps also for that of Southern States.
39. *BIG-TREE* (*Sequoia washingtoniana* (Winsl.) Sudw.) Height, 350 feet +; diameter, 35 feet +.	California; very local and isolated.	Moist situations, between 4,000 and 6,000 feet. Probably only of historical interest.

B. BROAD-LEAFED TREES.

(With few exceptions these trees are deciduous.) Neither a strictly botanical nor a strictly practical classification in large groups has been attempted, but a sequence within botanical relations, and an arrangement according to the nature of the seed has been more or less observed, placing first the acorn and nut-bearing trees, next those with hard, wingless seeds, and lastly, those with soft and winged seeds.

THE OAKS.—Wood very variable, usually very heavy and hard, very strong and tough, porous, and of coarse texture; the sapwood whitish, the heart "oak" brown to reddish brown. It shrinks and checks badly, giving trouble in seasoning, but stands well, is durable, and little subject to attacks of insects. Oak is used for many purposes: In shipbuilding, for heavy construction, in common carpentry, in furniture, car, and wagon work, cooperage, turnery, and even in wood carving; also in the manufacture of all kinds of farm implements, wooden mill machinery, for piles and wharves, railway ties, etc. The oaks are medium to large-sized trees, forming the predominant part of a large portion of our broad-leafed forests, so that these are generally "oak forests," though they always contain a considerable proportion of other kinds of trees. Three well-marked kinds—white, red, and live oak—are distinguished and kept separate in the market. Of the two principal kinds white oak is the stronger, tougher, less porous, and more durable. Red oak is usually of coarser texture, more porous, often brittle, less durable, and even more troublesome in seasoning than white oak. In carpentry and furniture work, red oak brings about the same price at present as white oak. The red oaks everywhere accompany the white oaks, and, like the latter, are usually represented by several species in any given locality. Live oak, once largely employed in shipbuilding, possesses all the good qualities (except that of size) of white oak, even to a greater degree. It is one of the heaviest, hardest, and most durable building timbers of this country; in structure it resembles the red oaks, but is much less porous.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
40. **WHITE OAK** (*Quercus alba* Linn.) Height, 100 feet +; diameter, 3 feet +.	North Central, Central and Eastern States. Best development on western slopes of Allegheny Mountains and valley of Ohio River.	Grows well on a great variety of soils, but best on deep, moderately moist, well-drained, loamy sand, and in warm situations. Slow but persistent grower; light-needing; capable of enduring shade, but not with advantage. Most valuable of the American oaks.
41. **COW OAK** (SWAMP CHESTNUT OAK, BASKET OAK.) (*Quercus michauxii* Nutt.) Height, 100 feet +; diameter, 3 feet +.	Southeastern. Best development on the rich bottom lands of southeastern Arkansas and Louisiana.	Moist, rich soil; will endure flooding. The most valuable of the White Oaks for the Gulf States.
42. **CHINQUAPIN OAK** (*Quercus acuminata* (Michx.) Houba.) Height, 80 feet +; diameter, 3 feet +.	Central and Middle Atlantic region. Largest growth in lower Ohio Valley.	Best in deep, rich, moist, well-drained bottom lands, but grows well and is not uncommon on dry, fertile, limestone soils; it also succeeds on clayey and sandy soils of uplands.
43. LIVE OAK (*Quercus virginiana* Miller.) Height, 80 feet +; diameter, 3 feet +.	Southern States. Greatest development in southern Atlantic States.	Warm, loamy soil, retentive of moisture, and free from over flow. One of the most *rapid* growers *of all the oaks; most shade-enduring;* evergreen foliage. Especially desirable for Southern forestry.

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and uses of their wood—Continued.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
44. *CAÑON LIVE OAK* (MAUL OAK. VALPARAISO OAK.) (*Quercus chrysolepis* Liebm.) Height, 80 feet +; diameter, 5 feet +.	Pacific States, 3,000 to 8,000 feet elevation.	Warm, dry, sunny exposures. Foliage evergreen.
45. TAN-BARK OAK (PEACH OAK.) (*Quercus densiflora* Hook. & Arnott.) Height, 60 feet +; diameter, 2 feet +.	Pacific coast. Best development in redwood belt on California coast.	Well drained, rich soils. Shade-enduring. Foliage evergreen.
46. CHESTNUT OAK (ROCK CHESTNUT OAK.) (*Quercus prinus* Linn.) Height, 80 feet +; diameter, 3 feet +.	Northeastern. Best development in southern Allegheny Mountains.	For planting on rocky banks and hillsides; never in any but well-drained situations.
47. **BUR OAK** (MOSSY-CUP OAK. OVERCUP OAK.) (*Quercus macrocarpa* Michx.) Height, 100 feet +; diameter, 3½ feet +.	Mainly Northeastern United States; extends farthest west and northwest of any of the Eastern oaks.	Requires better soil than White Oak—deep, rich loam; more shade-enduring. A Western substitute for White Oak, and especially recommended for prairie planting.
48. **POST OAK** (IRON OAK.) (*Quercus minor* (Marsh.) Sarg.) Height, 80 feet +; diameter, 2½ feet +.	East of the Rocky Mountains	Well-drained gravelly uplands, clay barrens, and poor sandy loams. Recommended for Western planting.
49. OVERCUP OAK (*Quercus lyrata* Walt.) Height, 80 feet +; diameter, 2 feet +.	Southeastern United States. Best developed in Arkansas and adjacent Texas.	Chiefly in wet or submerged swamps, but grows well in well-drained bottom lands and on rich, gravelly, or sandy loam uplands.
50. SWAMP WHITE OAK (*Quercus platanoides* (Lam.) Sudw.) Height, 90 feet +; diameter, 2 feet +.	Northeastern United States. Best development in region south of the Great Lakes.	In deep moist or inundated swamps and low banks of water courses. Succeeds in all loose, rich, fairly moist upland soils.
51. **RED OAK** (*Quercus rubra* Linn.) Height, 100 feet +; diameter, 3½ feet +.	East of Rocky Mountains. Most northerly of Atlantic oaks. Best development in Massachusetts.	Thrives in all soils, except an undrained one. The most *rapid* in growth of all the oaks. Sprouts vigorously from stump; of importance for tan-bark coppices.
52. **BLACK OAK** (YELLOW-BARK OAK. YELLOW OAK. QUERCITRON OAK.) (*Quercus velutina* Lam.) Height, 80 feet +; diameter, 3 feet +.	East of longitude 96°, United States. Best development in North Atlantic States.	Gravelly uplands; poorer soils than White Oak requires. Next to the Red Oak in rapidity of growth.
53. SPANISH OAK (RED OAK.) (*Quercus digitata* (Marsh.) Sudw.) Height, 80 feet +; diameter, 3 feet +.	Central, Southeastern, and Southern States. Best development in South Atlantic and Gulf States.	Dry, barren soils; rapid grower.
54. WATER OAK (DUCK OAK. POSSUM OAK. SPOTTED OAK.) (*Quercus nigra* Linn.) Height, 75 feet +; diameter, 3 feet +.	Central, Southern, and Southeastern States. Greatest development in eastern Gulf region.	Heavy undrained soil; exceedingly rapid grower. A useful *concomitant* in Southern planting.

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and uses of their wood—Continued.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth
55. **BEECH** (*Fagus atropunicea* (Marsh.) Sudw.) Height, 100 feet +; diameter, 3 feet +.	East of Mississippi and Missouri rivers. Best development probably on "bluff" formations of Lower Mississippi basin.	Fresh, rich, but not necessarily a deep soil; limestone soils. For rocky, exposed situations. Rapid grower and *enduring shade* exceedingly well, a fact which renders it one of the most valuable aids in forestry.
56. CHESTNUT (*Castanea dentata* (Marsh.) Borkh.) Height, 90 feet +; diameter, 14 feet +.	Northeastern and Middle Atlantic States. Best development on western slopes of Allegheny Mountains.	*Well drained* gravelly soils; succeeds on rocky hillsides with soil of sufficient looseness and depth; on northern and eastern exposures; will thrive on rather poor sand, slow and uncertain in stiff, clayey soil; on limestone only when well fissured. Exceedingly *rapid* grower; moderately shade-enduring; sprouts most vigorously and *persistently* from the stump; *large yield per acre.*
57. **BLACK WALNUT** (*Juglans nigra* Linn.) Height, 100 feet +; diameter, 4 feet +.	Northeastern, Central, and Southeastern States. Best development on southern slopes of Allegheny Mountains and in bottom lands of southwestern Arkansas and Indian Territory.	Deep, loose, fresh to moist, warm, and sandy loam; will grow in a dry and compact soil, but not in a wet one. Hardy and rapid grower, especially in height; only centenarians produce first-class quality of lumber, but useful timber may be produced in 40 to 60 years. Sprouts freely from the stump. Not recommended for arid or subarid regions nor for uplands.
58. *BUTTERNUT* (WHITE WALNUT.) (*Juglans cinerea* Linn.) Height, 80 feet +; diameter, 2 feet +.	Northeastern States. Best development in basin of Ohio River.	Prefers a deep, rich, *cool* loam; suited to cooler sites and colder climate than the foregoing species. Rapid grower when young.

THE HICKORIES, AND OTHER HARD-SEEDED VARIETIES.—*The Hickories.*—Wood very heavy, hard, and strong, tough, of rather coarse texture, smooth, and of straight grain. The broad sapwood white, the heart reddish nut brown. It dries slowly, shrinks and checks considerably; is not durable in the ground, or if exposed, and, especially the sapwood, is always subject to the inroads of boring insects. Hickory excels as carriage and wagon stock, but is also extensively used in the manufacture of implements and machinery, for tool handles, timber pins, for harness work, and cooperage. The hickories are tall trees with slender stems, never form forests, occasionally small groves, but usually occur scattered among other broad-leafed trees in suitable localities. The following species all contribute more or less to the hickory of the markets:

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
59. **SHAGBARK HICKORY.** (SHELLBARK HICKORY.) (*Hicoria ovata* (Mill.) Britt.) Height, 100 feet +; diameter, 2 feet +.	Eastern United States; wide range. Best development west of the Allegheny Mountains.	Deep, fresh soil; a compact soil not objectionable; not on poor, dry, or wet soils. At first slow, but afterwards rapid grower; sprouts well from the stump. Moderately shade enduring. Somewhat liable to injury by frost.
60. BITTERNUT (PIGNUT. SWAMP HICKORY.) (*Hicoria minima* (Marsh.) Britt.) Height, 80 feet +; diameter, 2 feet +.	Eastern United States; wide range.	To replace Shagbark Hickory on low, moist, or wet ground. Sprouts well from the stump. Less liable to frost than Shagbark Hickory, but more subject to the ravages of insects.
61. MOCKERNUT (BULLNUT. KINGNUT. BLACK HICKORY. BIGBUD HICKORY. WHITEHEART HICKORY.) (*Hicoria alba* (Linn.) Britt.) Height, 90 feet +; diameter, 3 feet +.	Eastern United States; wide range. Most abundant and generally distributed in the Southern States.	To replace Shagbark Hickory on poorer and drier soils; will succeed even on *barrens.* Sprouts well from the stump, but slow grower; liable to attacks of insects.
62. SHELLBARK HICKORY (BOTTOM SHELLBARK.) (*Hicoria laciniosa* (Michx. f.) Sarg.) Height, 70 feet +; diameter, 3 feet +.	Central United States; local.	Rich, deep soil; especially adapted to well-drained bottom lands, but succeeds with slower growth on drier uplands. Climatically confined.

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and uses of their wood—Continued.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
63. **PECAN** (ILLINOIS NUT.) (*Hicoria pecan* (Marsh.) Britt.) Height, 75 feet +; diameter, 2 feet +.	Southwestern, but widely cultivated in Southern States. Best development in Arkansas and Indian Territory.	Deep, rich bottom land, but succeeds fairly on upland soils of moderate richness. Rapid grower; for Southwestern planting. More valuable perhaps for production of fruit than for timber purposes.
64. **BLACK CHERRY** (RUM CHERRY.) (*Prunus serotina* Ehrhart.) Height, 90 feet +; diameter, 2 feet +.	Eastern United States; wide range.	Adapted to almost any soil and situation; best in deep, well-drained soil; will succeed also on dry soil. Very rapid grower, very soon reaching a useful size for cabinet wood. Endures considerable *shade* when young. The *wide range of sites* to which it is adapted, its rapid growth and endurance of shade place it among the most valuable forest trees of the United States, especially for Western planting. Not infected by caterpillars in forest plantations.
65. SWEET GUM (LIQUIDAMBER. RED GUM. STAR-LEAVED GUM. BILSTED.) (*Liquidambar styraciflua* Linn.) Height, 100 feet +; diameter, 3 feet +.	Southeastern States. Greatest development in basin of Mississippi River.	Succeeds on a great variety of soils; a tree of the swamp as well as of dry soils; best on light, dry, sandy, and soils retentive of moisture. Rapid grower. Insect proof and generally healthy.
66. LOCUST (LOCUST. YELLOW LOCUST.) (*Robinia pseudacacia* Linn.) Height, 80 feet +; diameter, $1\frac{1}{2}$ feet +.	Southern Allegheny region. Allegheny Mountains; local; but by cultivation widely distributed east of Rocky Mountains.	Poor, loose sands give best quality of timber; not succeeding well in compact soils, but will thrive on a thin one, and grows quickest on a rich, sandy loam. Very *rapid* grower while young; needs light very much; sprouts *persistently* and *vigorously* from the roots. To be only sparingly dispersed among shady companions, which will afford protection against the attacks of borers. Easily propagated from seed, also by cuttings, suckers, and stakes. For short rotations and coppice management.
67. HONEY LOCUST (SWEET LOCUST. HONEY SHUCKS. THREE-THORNED ACACIA. BLACK LOCUST.) (*Gleditsia triacanthos* Linn.) Height, 90 feet +; diameter, 2 feet +.	Central States. Best development in bottom land of lower Ohio River basin. Widely cultivated for hedges and ornament.	Low, rich bottom land; rarely on high, dry, sterile hills; but often common on rich uplands, where it grows rapidly. Very *rapid grower; needs light.* *Easily* grown from seed, but not from cuttings. Less liable to insect ravages; otherwise to be treated like Black Locust, which it is recommended to replace in Southern localities.
68. *HACKBERRY* (NETTLE-TREE.) (*Celtis occidentalis* Linn.) Height, 80 feet +; diameter, 3 feet +.	Northern and mainly east of the Rocky Mountains. Best development in basin of Ohio River.	Will grow tolerably well on the most barren and poorest soils, but best in a fertile one, cool and moist, where it is of rapid growth. In Western planting recommended only as an adjunct.
69. *RED MULBERRY* (*Morus rubra* Linn.) Height, 60 feet +; diameter, 2 feet +.	East of longitude 98°. Best development in basins of lower Ohio and Mississippi rivers.	Deep, rich loam, but grows well on poorer dry soil; endures shade. For Southwestern planting.
70. *MAGNOLIA* (SOUTHERN EVERGREEN. BIG LAUREL. BULL BAY.) (*Magnolia fœtida* (Linn) Sarg.) Height, 70 feet +; diameter, 2 feet.	Southern and Gulf States. Best development along Mississippi in Gulf region.	Cool, moist hummocks, with rich, deep, loose soil. Not hardy in Northern States; for strictly Southern climate.
71. CUCUMBER TREE (*Magnolia acuminata* Linn.) Height, 90 feet +; diameter, 3 feet +.	Mainly Middle Atlantic region. Best development in the southern Allegheny Mountain region.	In cool, moist, deep, rich soils of mountain slopes, valleys, and "coves." Succeeds also in fresh sandy or gravelly soils of moderate richness.
72. **TULIP-TREE** (WHITE WOOD. YELLOW POPLAR.) (*Liriodendron tulipifera* Linn.) Height, 120 feet +; diameter, 4 feet +.	Eastern States. Greatest development in valley of lower Wabash River, and on western slope of Allegheny Mountains in Tennessee, North Carolina, and the Virginias.	Deep, light, loamy, sandy, or clayey soils, in cool, moist situations. Tolerably rapid and persistent grower. Needs light very much; hardy. Poor seeder, and low percentage of germination; seed to "lie over." Sprouts fairly from stump. One of the largest and most valuable of the deciduous soft woods.

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and uses of their wood—Continued.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
73. HARDY CATALPA (*Catalpa speciosa* Warder.) Height, 80 feet +; diameter, 3 feet +.	South Central States; rare, but widely cultivated for ornament. Best development in valley of lower Wabash River.	Adapted to a great variety of soils; best on low, rich bottom lands. Very rapid grower; sprouts vigorously from the stump; *shade enduring*. Good seeder and keeper. Readily propagated from seed, cuttings, and layers. Desirable tree for Western planting. Foliage subject to ravages of insects.
74. COMMON CATALPA (*Catalpa catalpa* (Linn.) Karst.) Height, 40 feet +; diameter, 1½ feet +.	Gulf States, but widely cultivated for ornament.	Like the preceding, to be used in Southwestern planting, to which it is best adapted.

THE ASHES, MAPLES, ELMS, ETC.—The wood of the ashes is heavy, hard, strong, stiff, quite tough, not durable in contact with soil, straight grained, rough on the split surface, and coarse in texture. The wood shrinks moderately, seasons with little injury, "stands" well, and takes a good polish. In carpentry ash is used for finishing lumber, stairways, panels, etc.; it is used in shipbuilding, in the construction of cars, wagons, carriages, etc., in the manufacture of farm implements, machinery, and especially of furniture of all kinds, and also for harness work; for barrels, baskets, oars, tool handles, hoops, clothespins, and toys. The trees of the several species of ash are rapid growers, of small to medium height, with stout trunks; they form no forests, but occur scattered in almost all our broad-leaved forests.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
75. **WHITE ASH** (*Fraxinus americana* Linn.) Height, 100 feet +; diameter, 3 feet +.	Eastern; wide range Best development in lower Ohio basin.	Depth, looseness, and moisture of soil of most importance. Best in moist atmosphere of northern and eastern exposures. Will succeed in wet and compact soil if well drained, but maintains itself with slow growth in a light and dry one. Rapid grower; light needing, thinning out rapidly, and therefore requiring shady, slower-growing companions. Sprouts vigorously and persistently from the stump. Often a poor seeder; seed not easily kept, tending to "lie over." Liable to attacks of borer and to frost when young.
76. **BLACK ASH** (HOOP ASH. GROUND ASH.) (*Fraxinus nigra* Marsh.) Height, 90 feet +; diameter, 2½ feet +.	Northern and Northeastern States. The most northerly of the ashes.	Soils like those for *F. americana*, but *indifferent* to *drainage*, and more dependent on moisture; therefore well adapted to undrained situations in cool climate; otherwise like *americana*.
77. GREEN ASH (*Fraxinus lanceolata* Borkh.) Height, 50 feet +; diameter, 1½ feet +.	Western States east of Rocky Mountains and South; most common and best developed in the Mississippi Valley.	Less dependent on humidity of soil than the White Ash, but prefers a deep, cool, moist soil, and will succeed even on inundated lands. Rapid but not persistent grower. Seed germinates readily. The ash for Western planting.
78. BLUE ASH (*Fraxinus quadrangulata* Michx.) Height, 70 feet +; diameter, 2 feet +.	Central States Best development in basin of lower Wabash River.	Less dependent on moisture than other ashes; prefers a rich, deep, moist soil, and grows well on dry limestone soils. Recommended for Western planting.
79. OREGON ASH (*Fraxinus oregona* Nutt.) Height, 60 feet +; diameter, 1½ feet +.	Northwestern coast region Best development in bottom lands of southwestern Oregon.	Moist soils and climate.
80. **SUGAR MAPLE** (HARD MAPLE. SUGAR-TREE.) (*Acer saccharum* Marsh.) Height, 100 feet +; diameter, 3 feet +.	Eastern United States and northward. Best development in region of the Great Lakes.	Best on moderately deep, loose, well-drained, strong, loamy, and calcareous soil, in moist, cool position; will grow also on stiff clay, if not too wet, and on stony hillsides, if not too dry. Tolerably rapid and persistent grower; moderately shade enduring; does not sprout well from the stump. Not well adapted to dry regions.
81. SILVER MAPLE (WHITE MAPLE. SOFT MAPLE.) (*Acer saccharinum* Linn.) Height, 90 feet +; diameter, 3 feet +.	Eastern United States Best development in basin of lower Ohio River.	Adapted to a variety of soils and climates, but best on rich, moist soil. *Very rapid* but not persistent grower; light needing; sprouts vigorously from the stump; liable to injury from winds; comparatively free from insects. Especially recommended as a nurse in Western planting.

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and uses of their wood—Continued.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
82. RED MAPLE (SOFT MAPLE. WATER MAPLE. SWAMP MAPLE.) (*Acer rubrum* Linn.) Height, 90 feet +; diameter, 3 feet +.	Eastern United States and northward; wide range. Greatest development in valleys of lower Wabash and Yazoo rivers.	Best on low, wet soils, but will thrive in moderately dry situations. Rapid, but moderately persistent grower; endures more *shade* than *A. saccharinum* L.; sprouts vigorously from the stump. Usefulness in dry climates questionable.
83. OREGON MAPLE (CALIFORNIA MAPLE. BROAD-LEAFED MAPLE.) (*Acer macrophyllum* Pursh.) Height, 90 feet +; diameter, 4 feet +.	Pacific slope. Best development on rich bottom lands of southern Oregon.	Rich bottom lands. Rapid grower in moist climate. Important on the Pacific slope.
84. *BOX ELDER* (ASH-LEAVED MAPLE.) (*Acer negundo* Linn.) Height, 50 feet +; diameter, 2 feet +.	East of Rocky Mountains, rather Southern and Western. Best development in valleys of Wabash and Cumberland rivers.	Best on low, rich ground, but will succeed on upland. Rapid but not persistent grower; sprouts well from the stump; hardy. *Easily propagated.* For forestry purposes, important only as *nurse* and soil cover, especially in Western planting.
85. **WHITE ELM** (AMERICAN ELM. WATER ELM.) (*Ulmus americana* Linn.) Height, 100 feet +; diameter, 3½ +.	East of the Rocky Mountains. Probably attains its best developments near its northern limits.	Adapted to a great variety of soils, but best on a rich, loose, moist one; requires less moisture than the ashes; bears occasional flooding. Rapid and persistent grower; sprouts well; endures moderate shade. Important in forestry mainly as a *nurse* and for soil cover. Recommended for Western planting.
86. **CORK ELM** (HICKORY ELM. WHITE ELM. CLIFF ELM.) (*Ulmus racemosa* Thomas.) Height, 90 feet +; diameter, 2 feet +.	Northeastern United States. Best development in southern Ontario and Michigan.	Rich, moist, heavy, loamy soils. Probably to take the place of the White Elm in forestry.
87. *WING ELM* (*Ulmus alata* Michx.) Height, 80 feet +; diameter, 2 feet +.	Southeastern United States. Best development west of the Mississippi River.	Most commonly on dry, gravelly uplands, but frequently in moist bottoms and along water courses. Very adaptive, and to be used in Southwestern planting in place of the White Elm.
88. *SLIPPERY ELM* (RED ELM. MOOSE ELM.) (*Ulmus pubescens* Thomas.) Height, 60 feet +; diameter, 2 feet +.	Northern Atlantic and Gulf States. Best development in Western States.	Rich, moist, well-drained soil; much like that of the White Elm, but will bear drier and more elevated situations. Rapid but not persistent grower. Easily propagated.
89. YELLOW BIRCH (GRAY BIRCH.) (*Betula lutea* Michx. f.) Height, 80 feet +; diameter, 3 feet +.	Northeastern United States and northward. Best development north of the Great Lakes.	Cool, moist atmosphere preferable. Capable of thriving on poor, but best on a moderately deep, loose, moist sand; hardy and very adaptive as to soils. Rapid and tolerably persistent grower; sprouting qualities greatly dependent on site. Vigorously in moist soils. Light needing. Easily propagated.
90. SWEET BIRCH (CHERRY BIRCH. MAHOGANY BIRCH.) (*Betula lenta* Linn.) Height, 60 feet +; diameter, 3 feet +.	Same range as Yellow Birch.	Same as above species, but apparently not as rapid nor as persistent a grower.
91. RIVER BIRCH (*Betula nigra* Linn.) Height, 80 feet +; diameter, 3 feet.	Eastern States. Best development in the South Atlantic and Lower Mississippi Valley regions.	Almost exclusively on moist or inundated bottoms, along streams, and near ponds. Succeeds very well on moist, rich, porous, upland soils. Important as a substitute for Northern birches in Southwestern planting.
92. *CANOE BIRCH* (WHITE BIRCH. PAPER BIRCH.) (*Betula papyrifera* Marshall.) Height, 60 feet +; diameter, 2 feet +.	Northwestern, Northern, and Northeastern in United States. Reaches a higher latitude than any other American deciduous tree.	Mostly on sandy soils in northern climates. Not on clay lands where the Yellow Birch thrives.

List of one hundred species of trees of the United States most valuable for timber, with notes on their range of distribution, cultural requirements, and the character and uses of their wood—Continued.

Name of species and limit of size.	Regions of abundant growth.	Soil and climate, and characteristics of growth.
93. *WHITE BIRCH* (OLD-FIELD BIRCH. GRAY BIRCH.) (*Betula populifolia* Marsh.) Height, 30 feet +; diameter, 1 foot +.	Northeastern coast region	Adapted to drier and poorer soils than other birches. Short-lived; rapid grower; *sprouts readily* from the stump. Probably least important of the birches.
94. **BASSWOOD** (AMERICAN LINDEN. BEE-TREE. LIME-TREE.) (*Tilia americana* Linn.) Height, 100 feet +; diameter, 3 feet +.	East of the Mississippi and Missouri rivers; wide range. Greatest development in valley of Lower Wabash River.	Deep, moderately loose, and somewhat moist soil; can endure a wet soil, but will not thrive on a dry one. Rapid and persistent grower; sprouts vigorously from the stump; endures moderate shade. Not very hardy, but in cool situations a desirable adjunct in forestry.
95. WHITE BASSWOOD (*Tilia heterophylla* Vent.) Height, 60 feet +; diameter, 3 feet +.	Middle and South Atlantic region. Best development in southern Alleghenies.	Deep, rich, moist, well-drained soils of mountain coves, lower slopes, and on the banks of streams; frequent also on rich limestone soils of the plain, and succeeds on dry, gravelly, clayey, and sandy soils of moderate richness; important for Southern planting in place of the Northern basswood.
96. SYCAMORE (BUTTONWOOD. BUTTONBALL-TREE. WATER BEECH.) (*Platanus occidentalis* Linn.) Height, 120 feet +; diameter, 6 feet +.	East of the Mississippi and Missouri rivers. Best development in bottom lands of the Ohio and Mississippi rivers.	Rich, moist soil, low ground, thriving in swamps subject to overflow; grows well on moist upland. Wide climatic range, but liable to frost when young; light needing; secondary in forestry.
97. COTTONWOOD (CAROLINA POPLAR. BIG COTTONWOOD. NECKLACE POPLAR.) (*Populus deltoides* Marsh.) Height, 100 feet +; diameter, 4 feet +.	East of the Rocky Mountains	Adapted to a variety of soils, but best in a moist, strong, loamy one. Exceedingly *rapid* grower; sprouts vigorously from the stump; light needing; *thinning out rapidly;* short-lived and exhaustive to the soil; most readily propagated. Has been recommended for planting on Western prairies, chiefly on account of its rapidity of growth, ease of procuring plant material, and of propagation. In forestry should be used only as a nurse with better and shady kinds.
98. *LARGE-TOOTH ASPEN* (WHITE POPLAR.) (*Populus grandidentata* Michx.) Height, 60 feet +; diameter, 2 feet +.	Northern and Northeastern States.	Northern States, in moist situations; grows well in all fresh upland soils.
99. *BALM OF GILEAD* (BALSAM POPLAR. TACAMAHAC.) (*Populus balsamifera* Linn.) Height, 70 feet +; diameter, 3 feet +.	Northern United States	A substitute for cottonwood in the most northern localities. Thrives in moist, rich, well-drained soils.
100. *ASPEN* (AMERICAN ASPEN.) (*Populus tremuloides* Michx.) Height, 50 feet +; diameter, 1½ feet +.	Northern and Southwestern (in United States); in Pacific region, from 6,000 to 10,000 feet elevation.	Of value mainly as a tree naturally covering denuded mountain sides and as a quick-growing nurse for better kinds.

NOTE 1.—Trees which may be looked to as capable of enduring more or less unfavorable sites:

Dry to barren soils: Nos. 2, 3, 4, 5, 11, 15, 30, 31, 47, 48, 53, 64, 66, 68, 82, 87, 93.

Insufficiently drained soils: Nos. 3, 9, 21, 28, 31, 32, 41, 50, 54, 65, 76, 82, 85, 86, 91, 96.

Stiff soils: Nos. 31, 32, 53, 54, 67, 73, 74, 77, 84, 85.

Prairie planting: Tried, Nos. 1, 4, 17, 25, 30, 31, 47, 51, 57, 59, 60, 62, 63, 64, 66, 67, 68, 70, 73, 75, 77, 78, 79, 81, 82, 84, 85, 87, 89. Worthy of trial, Nos. 2, 7, 11, 31, 40, 48, 69.

NOTE 2.—Of exotics which have been successfully introduced for forest culture, the following may be cited as deserving more or less attention:

Conifers: Scotch Pine (*Pinus sylvestris*, L.), Austrian Pine (*Pinus austriaca*, Hoss.), Corsican Pine (*Pinus laricio*, Poir.), Norway Spruce (*Picea excelsa*, D. C.), Nordmann's Fir (*Abies Nordmanniana*, Link.), European Larch (*Larix Europæa*, D. C.).

Broad-leafed trees: English Oak (*Quercus robur*, L.), Cork Oak (*Quercus suber*, Linn.), Black Alder (*Alnus glutinosa*, Gaertn.), Ailanthus (*Ailanthus glandulosus*, Desf.), Black Mulberry (*Morus nigra*, L.). Australian Gum Trees: *Eucalyptus globulus*, Labil., *E. rostrata*, Cav. Australian Wattle Trees: *Acacia decurrens*, Willd., *A. pycnantha*, Benth. Gray Poplar (*Populus canescens*, Smith).

Biological Studies.

As we shall see further on in this report the most important part of our forest resource is in the coniferous supplies, and among these especially in the pines, the white pine of the North and the yellow pine of the South. These latter covering vast areas, not less than 100,000,000 acres, furnish now, and will still more in the near future, the most important staples of our lumber industry, as the white pine supplies are giving out. There is still a possibility of treating the uncut balance of these pineries in such a manner as to secure their continued productiveness. The Division of Forestry, therefore, devoted much time and attention to the study of the economic, botanical, silvicultural, and technological features of these pines. The results have been embodied in a magnificent monograph (Bulletin 13), prepared by Dr. Charles A. Mohr, of Mobile, Ala.

To give an idea of the character of this work and at the same time a conception of the nature and development of these pines the following extracts and condensed statements are presented:

SOUTHERN LUMBER PINES.

The Southern States abound in those sandy soils which are the home of the pine tribes, and were once covered with seemingly boundless forests of the same. There are still large areas untouched, yet the greater portion of the primeval forest has not only been culled of its best timber, but the repeated conflagrations which follow the lumbering and, still more disastrously, the turpentine gatherers' operations have destroyed not only the remainder of the original growth, but the vegetable mold and the young aftergrowth, leaving thousands of square miles as blackened wastes, devoid of usefulness, and reducing by so much the potential wealth of the South.

There are, in general, four belts of pine forest of different types recognizable, their boundaries running in general direction somewhat parallel to the coast line: (1) The coast plain, or pine-barren flats, within the tidewater region, 10 to 30 miles wide, once occupied mainly by the most valuable of Southern timbers, the longleaf pine, now being replaced by Cuban and loblolly pines; (2) the rolling pine hills, or pine barrens proper, with a width of 50 to 120 miles, the true home of the longleaf pine, which occupies it almost by itself; (3) the belt of mixed growth of 20 to 60 miles in width, in which the longleaf pine loses its predominance, the shortleaf, the loblolly, and the hard woods associating and disputing territory with it; and (4) the shortleaf pine belt, where this species predominates on the sandy soils, the longleaf being entirely absent and the loblolly only a feeble competitor, hard woods being interspersed or occupying the better sites. Within the territory the species that occur occupy different situations. Thus the Cuban, which accompanies the longleaf, usually occupies the less well-drained situations, together with the loblolly, which, although it can accommodate itself to all soils, reaches its best development in the rich lowlands and is specially well developed in the flat woods which border the coast marshes of eastern Texas; where it associates with the shortleaf pine it also seeks the moister situation.

The longleaf and shortleaf pines are, in quantity and quality combined, the most important, while the loblolly or oldfield pine, as yet not fully appreciated, comes next, occupying large areas. The Cuban pine, usually known as slash pine—always cut and sold without distinction with the longleaf pine—a tree of as fine quality and of more rapid growth than the longleaf pine, is associated with the latter in the coast pine belt, scattered in single individuals or groups, but appears to increase in greater proportion in the young growth, being by its manner of development in early life better fitted to escape the dangers to which the aftergrowth is exposed.

Besides these four most important pines there are a number of others of less significance. The white pine (*Pinus strobus*) of the North extends its reign along the higher mountain regions of North Carolina into Georgia, forming a valuable timber tree, but of small extent. The spruce pine (*P. glabra*) develops into timber size, but is found only in small quantities and mostly scattered, and has therefore as yet not received attention in lumber markets; but its qualities, and especially its forestal value, being a pine which endures shade, will probably be appreciated in the future. The other four species of pine found in the South, namely, the black pine (*P. rigida*), the Jersey or scrub pine (*P. virginiana*), the spruce pine (*P. clausa*), the pond pine (*P. serotina*), do not or only rarely develop into timber trees of value, excepting that the scrub pine, occupying large areas of abandoned fields in Virginia, furnishes a considerable amount of firewood.

The greatest confusion exists in the names that are applied to these four lumber pines promiscuously.

FIG. 1.—LONGLEAF PINE FOREST IN LOUISIANA FLATS, VIRGIN, SCORCHED BY FIRE AS USUAL.

FIG. 2.—LONGLEAF PINE FOREST AFTER REMOVAL OF MERCHANTABLE TIMBER.

Market Names.

The various names under which Southern pine lumber appears in the market are either general or specific; the former being more or less general in application to lumber manufactured in the South, without reference to special localities, the latter referring to special localities from which the lumber is actually or presumably derived. In regard to the latter class of names it is to be regretted, perhaps, that they have been found necessary, the more because through their use not a few misconceptions and difficulties have arisen between consumers, manufacturers, and wholesale dealers, owing to the difficulty in defining what tree species furnish lumber included by such name or names.

The uninitiated may not understand that the various kinds of pine lumber manufactured in different States, although called by a specific name, may, after all, be of the same species and the same in all respects. "Florida long-leaved yellow pine" or "Florida pine" is in no way different from that cut and manufactured in Georgia under the distinctive name of "Georgia long-leaved yellow pine" or "Georgia pine." The question as to any difference of quality dependent upon locality of growth is as yet undecided.

The market names given to the various pines, uncertain as to their precise application in the minds of those that use them, or at least at variance with the conception of other authorities, are the following:

General—Yellow pine, Southern yellow pine, Southern pine, long-leaved yellow pine, long-leaved pine, hard pine, pitch-pine.

Specific—Virginia yellow pine, Virginia pine, North Carolina yellow pine, North Carolina pine, Georgia yellow pine, Georgia pitch-pine, Georgia pine, Georgia longleaf yellow, Georgia long-leaved pine, Florida yellow pine, Florida pine, Florida long-leaved pine, Texas yellow pine, Texas long-leaved pine.

The names "yellow pine," "Southern pine," seem first of all to be used as generic names, without distinction as to species. In the quotations from Western markets only "yellow pine" and "long-leaved yellow pine" or "long-leaved pine" are distinguished; the first name seemingly being now always used when "shortleaf" is meant, although it is also applied by advertisers from the longleaf-pine region to their product. In a market report of a leading lumber journal we find that "in the yellow pine line, longleaf, shortleaf, and curly pine can be bought," which would show that the attempt to distinguish the two kinds by their proper names is made. Curly pine, however, is in most cases longleaf pine with a wavy or curly grain, a sport, which is also found in the shortleaf species. Loblolly seems not to be quoted in the Western markets.

Formerly, while the longleaf pine was the only pine reaching the markets, it was commonly known under the name of "yellow pine," but now the supply under this name may be made up of all the species indiscriminately. In Texas and Louisiana "yellow pine" designates the longleaf species, in Arkansas and Missouri the shortleaf, while there the name "longleaf" is applied to the "loblolly," which is rarely cut.

In Florida, the Carolinas, and Georgia the name "yellow pine" is also used with less distinctive application. In Florida, besides the Cuban pine, which is never distinguished on the market, loblolly may also appear in the lumber pile. In Georgia and the Carolinas, although locally the name "yellow pine" is most frequently applied to the shortleaf, in the market a mixture of longleaf, shortleaf, loblolly, and Cuban pine satisfies the name.

In England, where probably nothing but longleaf pine is handled, the current name is "pitch-pine," and this name is also most commonly used in Georgia and North and South Carolina, strictly applying to longleaf pine. In Boston only Southern and hard pine is mentioned without distinction. It is in New York, Philadelphia, Baltimore, and other Atlantic markets that the greatest variety of names is used, with an attempt to distinguish two kinds, the longleaf and shortleaf, by using the name of the State from which the lumber is supposed to come, but neither the name nor the lumber pile agree always with the species that was to be represented.

"North Carolina pine," which is supposed to apply specifically to shortleaf, will be found to include in the pile also better qualities of loblolly, sometimes to the amount of 50 per cent. Longleaf forms only very occasionally a part of the supplies from this section.

"Georgia pine" is meant to designate the longleaf species, and, like "Florida pine," does mostly conform to this designation except as noted before under the name of yellow pine.

"Virginia pine" or "Virginia yellow pine" are names hardly known elsewhere than in the markets of Baltimore and Washington, where the bulk of the common building timber consists of it. It applies in the main to the loblolly, with a very small percentage of shortleaf making its way into the pile. While this is mostly coarse-grained inferior material, selected stuff, when well seasoned, furnishes good finishing and flooring material.

Field Names.

Field names are those applied to the four Southern pine lumber species in the tree and logs. Such names are usually more or less known to dealers and manufacturers, but, aside from the market names already discussed, have only lately been applied to lumber in the market.

Of the three pines, longleaf, shortleaf, and loblolly, the first alone is perfectly known by lumbermen and woodmen as a distinct "variety" (species). The remaining species, presenting to the lumberman's eye various forms according to the site producing the timber, are commonly supposed "varieties" or "crosses" more or less related to the longleaf pine. Specific differences in the lumber, both in appearance and quality, form, however, a sufficient basis of distinction as far as lumber is concerned, although this distinction is not necessarily carried out in putting lumber on the market.

A few of the names in common use are frequently applied by lumbermen to entirely different species from those usually known to botanists by the same name. The perplexity thus arising, upon the supposition that the common names of our botanical text-books are applied to the species by lumbermen, is not inconsiderable, and can doubtless be avoided only by a more careful attention on the part of the people to real specific distinctions.

The confusion in names is such that it is almost impossible to analyze properly the use of these names in the various regions. In the tabulated account of names on the next page, a geographical distribution has been given, as far as possible. Here only a few of the names are to be discussed.

"Pitch-pine" is the name most commonly applied to the longleaf in the Atlantic regions, and where it occurs associated with the shortleaf and loblolly the former is called "yellow pine" and the latter is called "shortleaf." The name "longleaf or long-leaved pine" is rarely heard in the field, "longstraw" being substituted.

The greatest difference of names and consequent confusion exists in the case of the loblolly, due no doubt to the great variety of localities which it occupies and consequent variety of habit of growth and quality. "Swamp" and "sap-pine" refer to comparatively young growth of the loblolly, coarse-grained, recognized by the rather deep longitudinal ridges of the bark, growing on low ground. "Slash-pine" in Virginia and North Carolina is applied to old well-developed trees of both loblolly and shortleaf; in Florida it is exclusively applied to the Cuban pine. When applied to the loblolly it designates a tree of fine grain, one half to two-thirds sap, recognized by the bark being broken into large, broad, smooth plates. This same form is also called "shortleaf pine" in North Carolina.

"Rosemary-pine" is a name peculiar to a growth of loblolly in the swamp region of the Carolinas, representing fully grown trees, fine grained, large amount of heart, and excellent quality, now nearly exhausted.

"Loblolly" or "old-field pine," as applied to *Pinus tæda*, is a name given to the second growth springing up on old fields in the North and South Carolinas, while in Alabama and Mississippi, etc., the "old-field" pine is applied to *Pinus echinata*.

The confusion arises mainly from an indiscriminate use of local names and from ignorance as to the differences in characteristics of their lumber, as well as the difficulty in describing these. Besides the names used in designating different species, there are names used by lumbermen to designate differences of quality in the same species and, in addition, names used in the markets without good distinction, until it becomes almost impossible to unravel the multiplicity of designations and define their meaning. Architects are apt to specify "Southern pine," not knowing that the greatest range of qualities can be supplied under that name; or refuse to accept "Texas" or "North Carolina pine" for "Georgia pine," although the same pine and quality can be furnished from either State. Dealers handle "longleaf pine" from Arkansas, where the timber that is understood by that name never grew. Millmen fill their orders for this pine, either overlooking differences or without knowing them.

CUBAN PINE FLATWOODS OF FLORIDA.

The following table of common names, which have been found applied to the four species furnishing Southern pine lumber, will most readily exhibit the difficulty arising from misapprehension of names. These names are used in the various markets and in various localities in the home of the trees. Where possible the locality in which the name is used has been placed in brackets by the side of the name.

Names of Southern lumber pines in use.

Botanical names.	*Pinus palustris* Miller. Syn. *P. australis* Michx.	*Pinus echinata* Miller. Syn. *Pinus mitis* Michx. *Pinus virginiana* var. *echinata* Du Roi. *P. Tæda* var. *variabilis* Aiton. *P. variabilus* Lamb. *P. rigida* Porcher.
Best common names. Local, market, and lumbermen's names.	LONGLEAF PINE: Southern yellow pine. Southern hard pine. Southern heart-pine. Southern pitch-pine. Hard pine (Miss., La.). Heart pine (N. C. and So. Atlantic). Pitch-pine (Atlantic). Long leaved yellow pine (Atlantic). Long-leaved pine (Atlantic). Long-leaved pitch-pine (Atlantic). Long-straw pine (Atlantic). North Carolina pitch-pine. Georgia yellow pine. Georgia pine. Georgia heart-pine. Georgia long-leaved pine. Georgia pitch pine. Florida yellow pine. Florida pine. Florida long-leaved pine. Texas yellow pine. Texas long-leaved pine.	SHORTLEAF PINE: Yellow pine (N. C., Va.). Short-leaved yellow pine. Short-leaved pine. Virginia yellow pine (in part). North Carolina yellow pine (in part). North Carolina pine (in part). Slash-pine (N. C., Va.), in part. Old-field pine (Ala., Miss.). Bull pine (?). Spruce-pine.
Botanical names.	*Pinus tæda* Linn. Syn. *Pinus Tæda* var. *tenuifolia* Aiton.	*Pinus cubensis* Griesebach. Syn. *Pinus Tæda* var. *heterophylla* Ell. *P. elliotii* Engelm. *P. cubensis* var. *terthrocarpa* Wright.
Best common names. Local, market, and lumbermen's names.	LOBLOLLY-PINE: Slash pine (Va., N. C.), in part. Loblolly pine (Gulf Region). Old-field pine (Gulf Region). Rosemary-pine (N. C., Va.). Short-leaved pine (Va. N. C., S. C.). Bull pine (Texas and Gulf Region). Virginia pine. Sap pine (Va., N. C.). Meadow pine (Fla.). Cornstalk pine (Va.). Black pine (Va.). Fox-tail pine (Va., Md.). Indian pine (Va., N. C.). Spruce-pine (Va.), in part. Bastard pine (Va., N. C.). Yellow pine (No Ala., N. C.). Swamp pine (Va. N. C.). Long-straw pine (Va., N. C.), in part.	CUBAN PINE: Slash-pine (Ga., Fla.). Swamp pine (Fla. and Ala.), in part. Bastard pine (Fla., Ala.). Meadow pine (Fla., E. Miss.), in part. She pitch-pine (Ga.).

The botanical distinctions can be briefly tabulated as follows:

Botanical diagnosis.

Species.	*Pinus palustris* Miller.	*Pinus cubensis* Griseb
Leaves	3 in a bundle, 9 to 12 (exceptionally 14 to 15) inches long.	2 and 3 in a bundle; 7 to 12 (usually 9 to 10) inches long.
Cones (open)	6 to 9 inches long, $4\frac{1}{2}$ to 5 inches in diameter	4 to $6\frac{1}{2}$ (usually 4 to 5) inches long; 3 to $4\frac{3}{4}$ inches in diameter.
Scales	$\frac{7}{8}$ to 1 inch broad; tips much wrinkled, light chestnut brown, gray with age.	$\frac{11}{16}$ to $\frac{7}{8}$ inch broad; tips wrinkled; deep russet brown; shiny.
Prickles	Very short, delicate, incurved	Very short; straight; declined.
Buds	$\frac{3}{4}$ inch long, $\frac{1}{2}$ inch in diameter; silver white	About $\frac{1}{2}$ inch long; $\frac{1}{4}$ inch in diameter; brownish.

Species.	*Pinus echinata* Miller.	*Pinus tæda* Linn.
Leaves	2 and 3 in a bundle; $1\frac{3}{8}$ to 4 inches long; commonly $2\frac{1}{2}$ to 4 inches.	3 in a bundle; 5 to 8 inches long.
Cones (open)	$1\frac{1}{4}$ to 2 inches long; $1\frac{1}{8}$ to $1\frac{3}{4}$ inches in diameter	$2\frac{1}{2}$ to $4\frac{1}{2}$ inches long; $1\frac{3}{4}$ to 3 inches in diameter.
Scales	$\frac{5}{16}$ to $\frac{3}{8}$ (exceptionally about $\frac{1}{2}$) inch broad; tips light yellow-brown.	$\frac{3}{8}$ to $\frac{3}{4}$ inch broad; tips smooth; dull yellow-brown.
Prickles	Exceedingly short ($\frac{1}{10}$ inch) delicate; straight, declined	Short; stout at base.
Buds	$\frac{3}{8}$ to $\frac{1}{2}$ inch long; about $\frac{1}{8}$ inch in diameter; brownish	$\frac{1}{2}$ to $\frac{3}{4}$ inch long; $\frac{1}{4}$ inch in diameter; brownish.

In aspect and habit the longleaf and Cuban pine somewhat resemble each other. The large silvery white buds of the longleaf pine, which constitutes its most striking character, and the candelabra-like naked branches with brush-like tufts of foliage at the end readily distinguish it from the Cuban pine, which bears a fuller and denser crown. The dark-green, glossy, and heavy foliage of the latter readily distinguishes this again from the loblolly, where these may appear associated, the latter having sea-green and thinner foliage.

As a rule, the Cuban pine grows taller (up to 110 or 115 feet, with a diameter of 2½ to 3 feet) than the longleaf, which rarely exceeds 105 feet and 20 to 36 inches in diameter. The Cuban pine forms massive horizontally spreading limbs, and at maturity a crown with rounded outlines. The longleaf pine forms a more flattened crown with massive but twisted gnarled limbs, which are sparingly branched.

The thin bark of the longleaf (only one-quarter to one-half inch thick), of uniform reddish brown color throughout, exfoliates in thin, almost transparent, rhombic flakes; the thick bark of the Cuban pine of the same color exfoliates in very thin, broad, purplish flakes.

The shortleaf pine is readily distinguished by the comparatively shorter and more scant appearance of its foliage. Moreover, this species is at once recognized by its characteristically small cones. Its habit is spreading, if compared with the more ascending, compact habit of the loblolly. At maturity the shortleaf has a much shorter bole (85 to 95 feet, diameter 1½ to 2 feet) than the loblolly (125 to 150 feet, diameter 4 to 5 feet), with which it is often associated, and a more pyramid-shaped crown.

The reddish bark of the shortleaf in mature trees is broken into long plates, while the loblolly bark appears of grayish color and breaks into broader, larger, and more deeply fissured plates.

Distribution and Habitat.

The geographical distribution of the areas within which these four pines occur and their commercial development in them are shown in the accompanying maps, prepared by Dr. Charles Mohr for the monograph referred to.

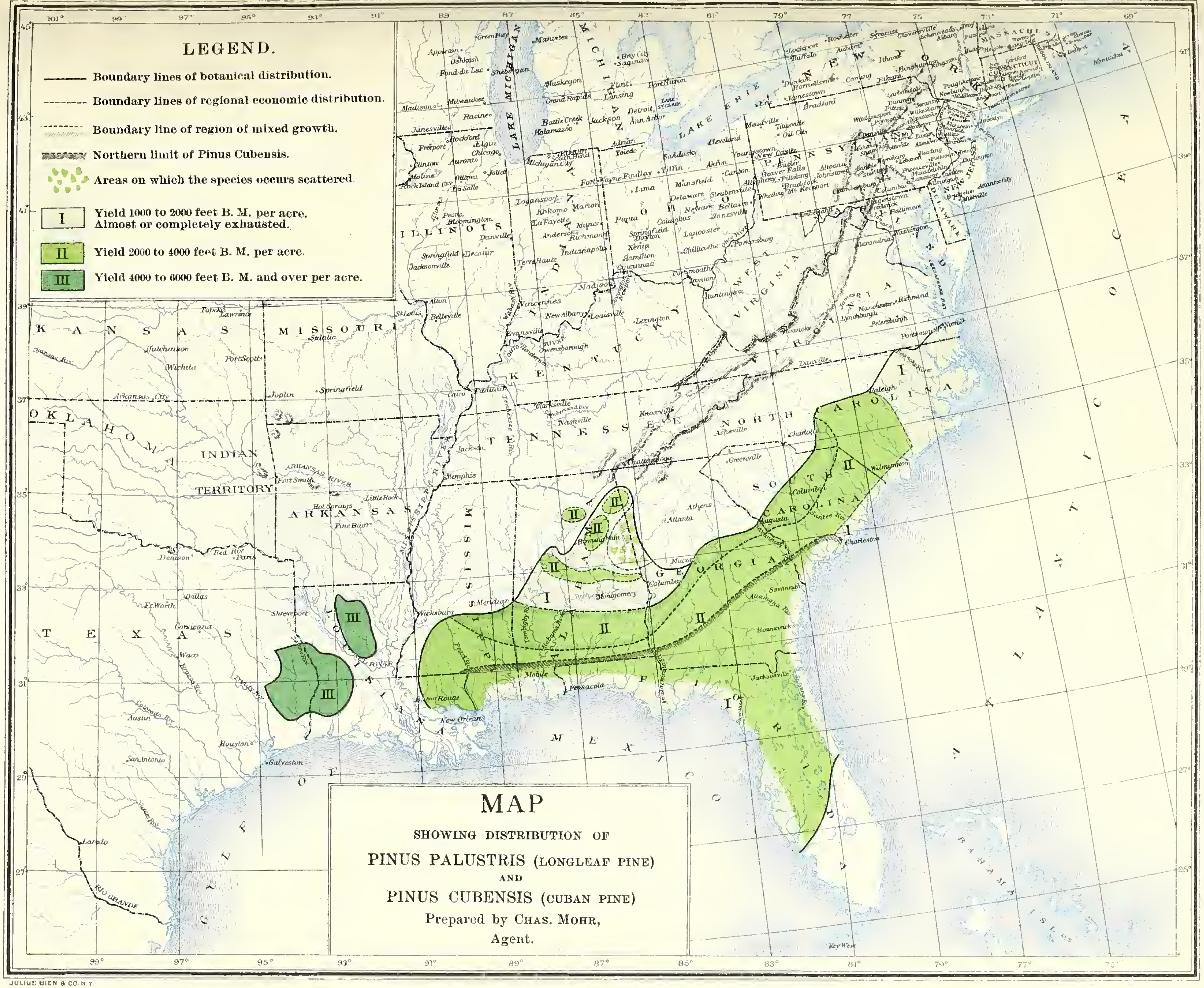
It is to be understood that not all the land within the boundaries indicated in the maps has been or is now covered by pine growth, but simply that within the lines the pines are found growing naturally. Nor is it to be understood that the areas which are indicated as producing a certain cut per acre do not contain places on which much more or much less lumber could be cut than the average figures given. These represent only a very general average for the region, based on conservative estimates, made for the purpose of showing more clearly the distribution in masses through the entire field of botanical distribution.

These approximations do not pretend to serve as guides to the purchaser of timber lands further than to indicate in what regions he is likely to find the pine sought for in greatest abundance and best development. A lumber dealer may also learn at one glance that he can not possibly be supplied with longleaf pine from a mill in Arkansas, nor with shortleaf pine from a mill on the Gulf coast, unless it be supplied with logs from inland.

Within the boundaries of geographical distribution each species is found to occupy certain soils and sites, which form its habitat. The habitat of the pines in general is found on sandy and mostly well-drained soils. In regard to moisture conditions of the soil, the different species adjust themselves differently. The longleaf pine is found (only exceptionally otherwise) on the best-drained, deep, sandy, siliceous alluvium, while the Cuban pine is confined to the moister flats or pine meadows of the coast, and will grow closely down to the sandy swamps, not objecting to clayey admixtures in the soil, but shunning the dry, sandy pine hills. The shortleaf pine prefers a well-drained, light, sandy or gravelly clay soil or warm light loam, while the loblolly, often struggling with the shortleaf for the possession of the soil, can adapt itself to wetter situations.

Extent of Merchantable Pine.

The entire region within which these pines occur in merchantable condition comprises about 230,000 square miles or, in round numbers, 147,000,000 acres; for land in farms, etc., 10,000,000 acres must be deducted, and allowing as much as two-thirds of the remainder as representing pine lands (the other to hard woods), we would have about 90,000,000 acres on which pine may occur. An average growth of 3,000 feet per acre—an extravagant figure when referred to such an area—



Scales
100 0 100 200 300 400 500 600 Miles

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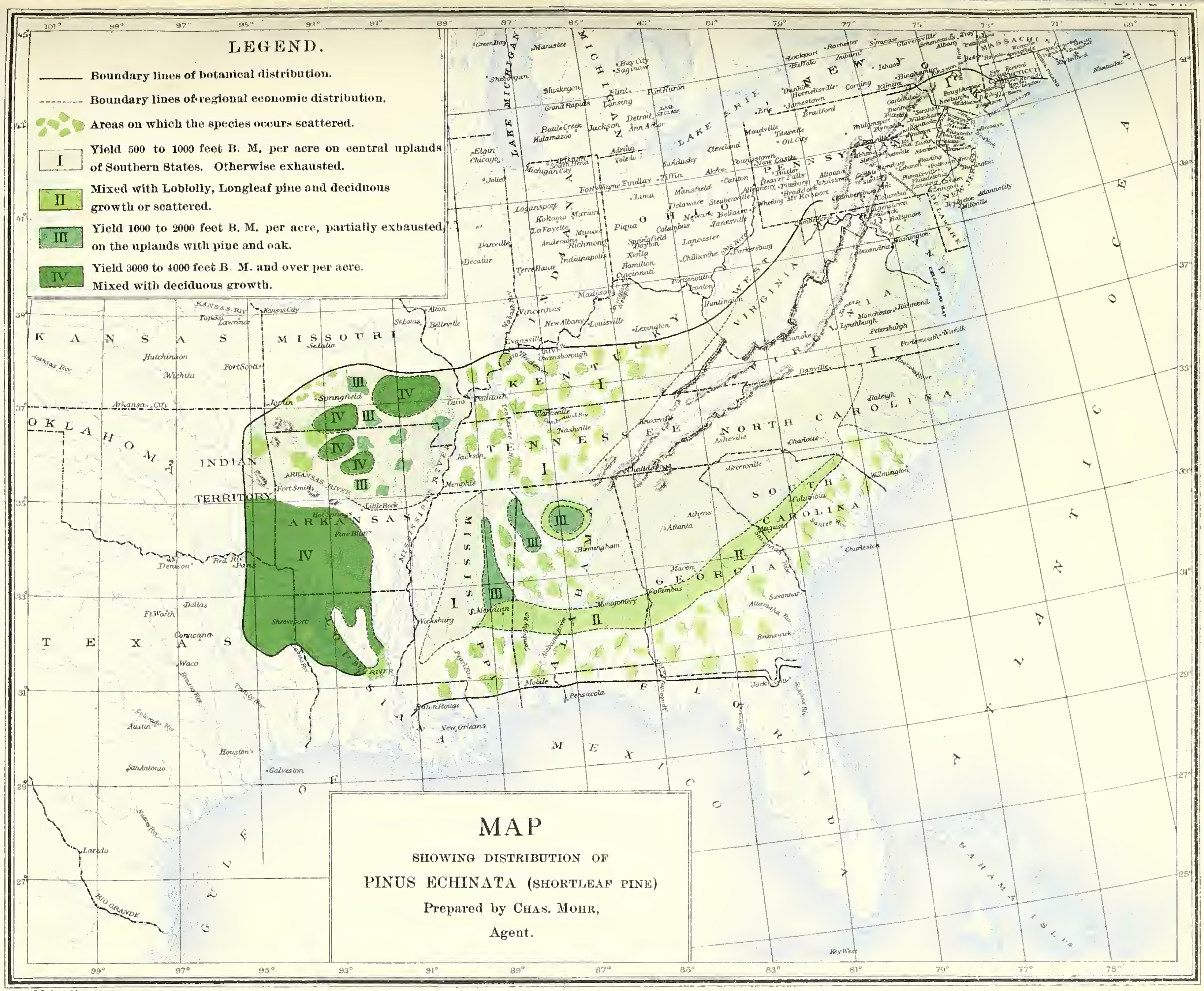

LEGEND.
Boundary lines of botanical distribution.
Boundary lines of regional economic distribution.
Areas on which the species occurs scattered.
I Yield 500 to 1000 feet B. M. per acre on central uplands of Southern States. Otherwise exhausted.
II Mixed with Loblolly, Longleaf pine and deciduous growth or scattered.
III Yield 1000 to 2000 feet B. M. per acre, partially exhausted, on the uplands with pine and oak.
IV Yield 3000 to 4000 feet B. M. and over per acre. Mixed with deciduous growth.
MAP
SHOWING DISTRIBUTION OF
PINUS ECHINATA (SHORTLEAF PINE)
Prepared by CHAS. MOHR,
Agent.
Scales
100 0 100 200 300 400 500 600 Miles
JULIUS BIEN & CO. N.Y.

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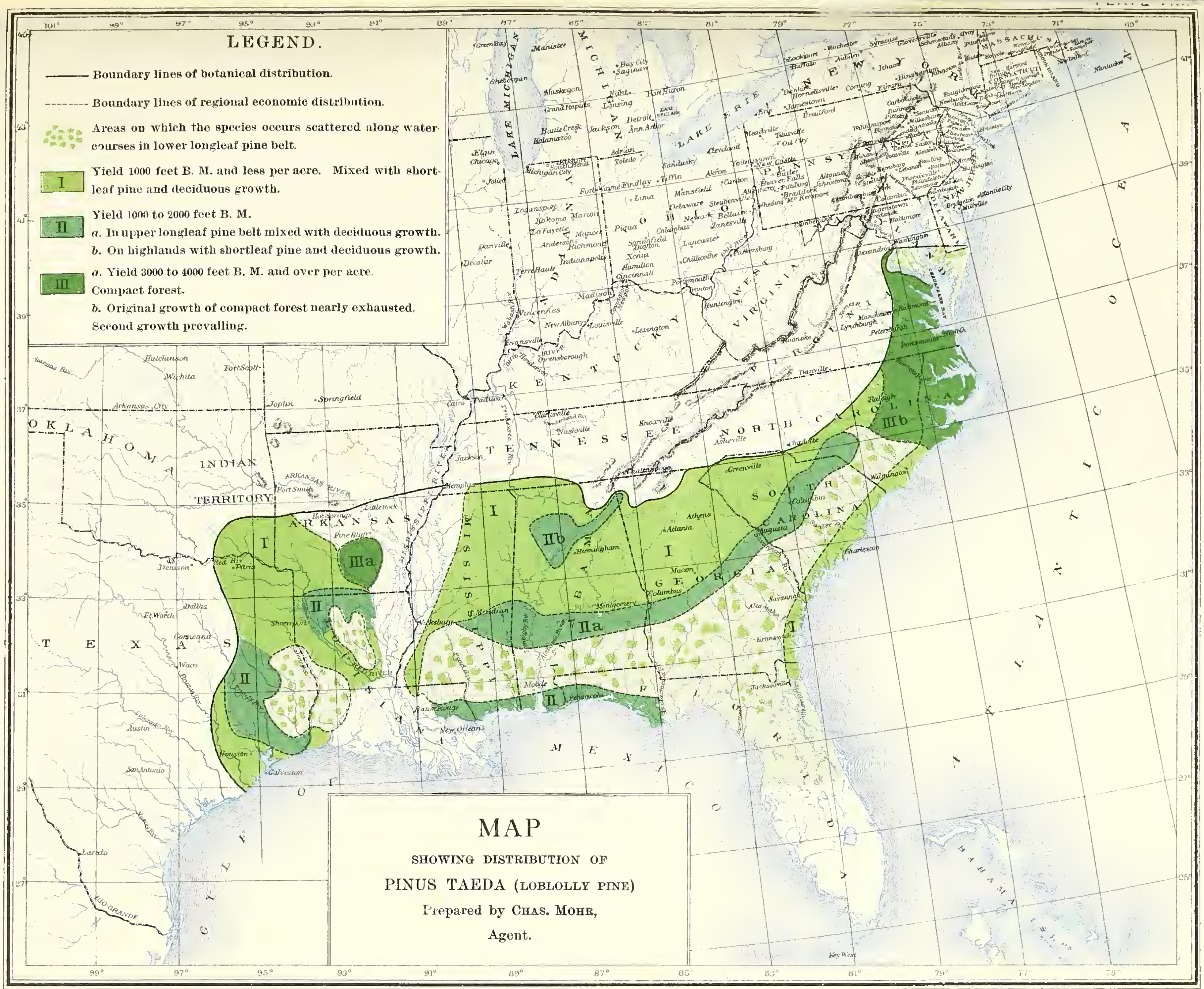

JULIUS BIEN & CO. N.Y.

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Scales
100 0 100 200 300 400 500 600 Miles

would make the possible stand 270,000,000,000 feet, provided it was in virgin condition and not mostly culled or cut.

The probability is that the amount of standing timber of such sizes as are at present marketable will fall far below 200,000,000, although by a reduction of the standard of marketable logs, which is now 8 to 10 inch as lowest diameters, it may be increased to 300,000,000 feet B. M., of which one-third may be accredited to the most valuable—the longleaf pine. The annual cut of these pines exceeds at present 7,000,000,000 feet B. M.

Those who rely upon the spontaneous natural reproduction of these pines to fill the gaps made in the virgin timber will do well to read the chapters on natural reproduction in Dr. Mohr's monograph on these pines, and the incidental remarks regarding the conditions for renewal and the appearance of the aftergrowth. If, in addition, they study the chapters on conditions of development, they will realize that the longleaf pine is bound to disappear largely even in the regions where it reigned supreme; that the Cuban pine, no despicable substitute, will take its place in the lower pine belt if allowed to propagate at all; but on large burnt areas the growth of scrubby oaks and brush will forever exclude this species, which eminently needs light. Loblolly and shortleaf, better fitted for warfare with other species, will do much in their respective habitats to recuperate, except in the mixed forest, where they are culled and the hard woods are left to shade out the aftergrowth, or where the continuous conflagrations have destroyed the mold and aftergrowth and given over the soil to scrubby brush growth, which for ages will either prevent the gradual return of the pines or impede their renewal and growth. Considering that the timber on which we now rely and on which we base our standards comes from trees usually from one hundred and fifty to two hundred years or more old, and that none of these pines makes respectable timber in less than from sixty to one hundred and twenty-five years, the necessity of timely attention to their renewal is further emphasized.

Characteristics of Distribution in Different Regions.

LONGLEAF PINE.

This pine occurs in all the South Atlantic and Gulf States at some distance from the coast, covering a belt of about 125 miles in width, interrupted only by the alluvial plains of the Mississippi and Red rivers in Louisiana and Texas. In addition, there is found in western Georgia and Alabama an extension in islands or patches northward to latitude 34.5°.

Within this range, going from the shore inland, the following divisions can be made: First, the coast plain, from 10 to 30 miles from seashore, contains only scattered growth on the grassy flats—the higher levels on which this pine prevailed are now mostly occupied by loblolly and Cuban pine; second, the rolling pine lands or pine barrens proper, covered with alluvial sands, are occupied almost entirely by this tree in perfection; third, the region of mixed growth, where this pine occupies in the main only the drift-covered ridges and is associated with the loblolly and shortleaf pines. Here it attains a larger size, with more full-sized trees per acre.

In Virginia this pine is almost extinct and replaced by loblolly. In North Carolina, through the agricultural district, this pine is mixed with loblolly and shortleaf and is of little importance down to the Neuse River. The forests exclusively of longleaf pine begin below Bogue Inlet, with a width of 95 to 125 miles inland, reaching down to the State line, covering about 6,500,000 acres; very largely tapped for turpentine.

In South Carolina the pine belt is about 150 miles wide; is mainly occupied by this pine, but on the hill lands is intermixed with the shortleaf. The southwestern plateau, with a porous sand soil, furnishes timber of excellent quality, much of which is still untouched.

In Georgia the flat woods of the shore are mostly stripped of this pine; the vast interior plain of about 17,000 square miles is almost exclusively covered with this tree.

In Florida the belt of longleaf pine of the Atlantic coast may be traced as far south as St. Augustine, being thence southward largely replaced by the Cuban pine. On the Gulf side more important longleaf growth is found farther southward, until the savannas and everglades are reached, where again the Cuban pine replaces it. In western Florida large areas are pretty well exhausted. The Gulf coast pine belt, covering some 40,000 square miles to the Mississippi River basin, shows no difference from the Atlantic forest.

The upper division of the pine belt or region of mixed growth in Alabama on a broken surface covers about 23,000 square miles, while the belt of drift deposit which crosses the State contains about 1,000 square miles, covered with longleaf pine of excellent quality and large yield per acre. The drift deposits along the Coosa River, covering about 300,000 acres, and a detached portion of drift in Walker County of 60,000 acres, are covered with pine of fine quality hardly yet touched.

Toward the west, in Louisiana, the coast-pine belt gradually passes into a mixed growth of shortleaf pine, oaks, and hickories on the uplands bordering the Mississippi. The slightly undulating flat woods of Louisiana support a better timber growth than is generally found in the upland pine barrens; but this forest has been largely invaded, while the pine-hill region of Louisiana has remained almost untouched. The pine region west of the Mississippi River, limited to the sands and gravels of the region, follows on their eastern boundary the valley of the Ouachita River for 150 miles.

In the center of the region above the Red River pine ridges alternate with tracts of oak and hickory. Toward the Red River the forests covering the undulating pine lands remain practically unbroken to the Sabine River. On the eastern side of the Red River the area is estimated at 1,625,000 acres, extending northward an average distance of 55 miles, cutting from 4,000 to 6,000 feet per acre, with no change in character to the Trinity River in Texas. In that State the forests of longleaf pine cover about 5,000 square miles, merging toward the north into the region of shortleaf, toward the south into vast forests of loblolly pine.

The fact that but little tapping for turpentine has been practiced in this region may be of importance from a market point of view.

CUBAN PINE.

This tree, which occurs mainly in the West Indies and South America, is confined within narrow limits in the United States, occupying the low coast plain of the Gulf States west of the Mississippi to a short distance beyond Pearl River, and of the Atlantic coast as far north as lower South Carolina, near Charleston. It is rarely found more than 40 or 50 miles inland, on the so-called pine flats or pine meadows. Only in southern Florida does it cross from Gulf to Ocean on the low ridges through the everglades. It occurs either scattered through other forest growth of the swamps or in groves along the borders of sandy swamps above perpetual overflow, mixed with longleaf or, more rarely, loblolly pine, excepting south of Cape Canaveral and Biscayne Bay, where it forms open forests by itself. Being able to thrive on pure sand as well as on the clay soils with poorer drainage, it is apt to crowd out the young growth of longleaf pine when the old trees of the latter have been cut. It is indiscriminately cut and made into lumber together with the longleaf pine without distinction. Its field of distribution is indicated on the map of the longleaf pine by patched area.

SHORTLEAF PINE.

This tree is more widely distributed than any of the other pines, namely, from the southern shores of Connecticut, where it occurs only scattered, to the treeless plains of Kansas and southward in the main to the northern line of the main body of the longleaf forests. It is mostly associated with deciduous-leaved trees, becoming the predominant forest growth in parts of northern Alabama, Mississippi, and western Louisiana. In northeastern Texas and southern Arkansas it covers large areas, to the exclusion of almost every other tree. While in the early history of this country this pine seems to have beeen a staple along the Atlantic coast up to New York, it occurs now only scattered and in commercially unimportant quantities north of Virginia. From here southward it covers large areas, occupying the higher inland parts of the maritime pine belt, mixed with other coniferous and deciduous growth, and throughout the interior of the Southern States into the mountainous region.

In North Carolina it is found from the coast to the mountains, and once formed about 25 per cent of the forest growth, now largely reduced. In South Carolina and Georgia it is similarly mixed in the upland forests of oak and hickory.

In Florida it is confined along the northern border of the State to a narrow strip of uplands, with a mixed growth of longleaf and hard-wood timber; in western Florida, where it is more rare, approaching the Gulf within 25 miles.

In Alabama and Mississippi it forms the larger part of the interior upland forest, in some sections becoming the prevailing tree, especially in the Warrior coal fields and in the northern part of the central drift belt to northeastern Mississippi, while it is more sparsely scattered through the growth of the upper coast pine belt.

But its best development evidently lies west of the Mississippi, occurring in greatest abundance and perfection in northeastern Texas, northwestern Louisiana, and southern Arkansas. In Texas, east of the Trinity River, it forms dense forests almost entirely by itself.

North of the Arkansas River it is found in smaller or larger areas, scattered through the upland regions to central Missouri. It is the pine of the Indian Territory, where large bodies occur, and of southwestern Missouri, and occurs also in Kansas as far north as the Osage River.

It is less frequent in Kentucky and Tennessee, being more confined to the eastern portions of those States. Only a single station is reported from southern Illinois, and its occurrence in the other parts of the field of distribution is mainly of botanical interest.

Since this tree occurs mainly in mixtures of different degree with other timbers, it is impossible to state yield per acre in general. In its western range, where it predominates, a cut of 3,500 to 4,000 feet B. M. per acre may be assumed. On the Atlantic coast supplies are largely reduced.

A rough guess places the possible standing timber of this species at 160,000,000,000 feet B. M.

LOBLOLLY PINE.

This pine is found in all the Southern States excepting Kentucky and Missouri, with its northernmost limit on the banks of the Rappahannock, below Washington, D. C. On the Atlantic slope it occupies the flat lands of the tide-water districts, either mixed with other species or forming compact bodies of timber. In Virginia it forms about 75 per cent of the timber standing east of the Richmond-Petersburg line, rapidly taking possession of abandoned fields. In North Carolina it associates with the longleaf pine, and is especially well developed in the low rich soil of the swamp borders, but here largely exhausted. Farther south in the pine barrens the longleaf pine prevails, and the loblolly is found only on the low borders of swamps and streams. In the Carolinas and Georgia it is also found inland to the foot of the mountains. In Florida it is rare, except in the northern part, being replaced southward by the Florida old-field pine (*P. clausa*).

About one-half of the pine timber on the flat, badly drained table-lands of the Warrior coal field in north Alabama consists of this pine, forming compact bodies of heavy timber or associated with hard woods. It abounds in Louisiana and southern Texas, in the flat woods bordering the coast marshes, and in the latter State an area of fully 6,800 square miles, south of the shortleaf pine uplands and west of the longleaf area, is covered by an almost continuous forest of the loblolly, of excellent growth, yielding from 4,500 to 5,000 feet per acre on the average.

Characteristics of the Wood.

No more difficult task could be set than to describe on paper the wood of these pines, or to give the distinctive features so that the kinds can be distinguished and recognized by the uninitiated. Only the combined simultaneous impressions upon all the senses permit the expert to make sure of distinguishing these woods without being able to analyze in detail the characters by which he so distinguishes them. While in many cases there would be no hesitation in referring a given stick to one or the other species, others may be found in which the resemblance to more than one species is so close as to make them hardly distinguishable. The following attempt to diagnose these woods must, therefore, be taken only as an imperfect general guide. So far, even microscopic examination has not furnished unfailing signs. Color is so variable that it can hardly serve as a distinguishing feature. The direction of the cut, roughness of surface, exudation of resin, condition of health, width of grain, moisture condition, even the mode of drying, exposure, etc., all have their share in giving color to the wood. Bearing in mind this great complication of color effects, it will be granted that descriptions of the same, disturbed by peculiarities of each separate observer, will aid but little in identifying the woods.

The sapwood of all the pines looks very nearly alike, and so does the heartwood. The color of the spring wood in the sap is a light yellowish with a shade of brown; the summer wood contains more brown, variable with the density of the cells and appearing darker when the bands

are more abruptly separated from the spring wood. The heartwood shows a markedly darker color with a reddish flesh-color tinge added.

It is perhaps easiest to distinguish the wood of the longleaf and Cuban pines from that of the shortleaf and loblolly. It is also possible to keep apart the longleaf from the Cuban; but while, in general, the shortleaf and loblolly can be more or less easily distinguished by color or grain, some forms of the latter (rosemary pine) so nearly resemble the former that no distinguishing feature is apparent.

The most ready means for distinguishing the four seems to be the specific gravity or weight in connection with the grain. The proportion of sap and heartwood will also be an aid in recognizing a log or log-run lumber in the pile. These distinctive features are tabulated as follows, the figures representing average conditions of merchantable timber and mature trees:

Diagnostic features of the wood.

Name of species.	Longleaf pine. (*Pinus palustris* Miller.)	Cuban pine. (*Pinus heterophylla* (Eli) Sudw.).
Specific gravity of kiln-dried wood. Possible range	.50 to .90	.50 to .90
Specific gravity of kiln-dried wood. Most frequent range	.55 to .65	.55 to .70
Weight, pounds per cubic foot, kiln-dried wood, average.	36	37
Character of grain seen in cross section	Fine and even; annual rings quite uniformly narrow on large logs, averaging generally 20 to 25 rings to the inch.	Variable and coarse; rings mostly wide, averaging on larger logs 10 to 20 rings to the inch.
Color, general appearance	Even dark reddish-yellow to reddish-brown	Dark straw color, with tinge of flesh color.
Sapwood, proportion	Little; rarely over 2 to 3 inches of radius	Broad, 3 to 6 inches.
Resin	Very abundant; parts often turning into "light wood;" pitchy throughout.	Abundant, sometimes yielding more pitch than Longleaf; "bleeds" freely, yielding little scrape.

Name of species.	Shortleaf pine. (*Pinus echinata* Miller.)	Loblolly pine. (*Pinus tæda* Linn.).
Specific gravity of kiln-dried wood. Possible range	.40 to .80	.40 to .80
Specific gravity of kiln-dried wood. Most frequent range	.45 to .55	.45 to .55
Weight, pounds per cubic foot, kiln-dried wood, average.	30	31
Character of grain seen in cross-section	Very variable; medium coarse; rings wide near heart, followed by zone of narrow rings; not less than 4 (mostly about 10 to 15) rings to the inch, but often very fine-grained.	Variable, mostly very coarse; 3 to 12 rings to the inch, generally wider than in shortleaf.
Color, general appearance	Whitish to reddish-brown.	Yellowish to reddish and orange brown.
Sapwood, proportion	Commonly 2 to 4 inches of radius	Very variable, 3 to 6 inches of the radius.
Resin	Moderately abundant, least pitchy; only near stumps, knots, and limbs.	Abundant; more than Shortleaf, less than Longleaf and Cuban, but does not "bleed" if tapped.

Quality and Adaptation of Woods.

The exhaustive research described in another part of this report has given a full answer to this part of the inquiry.

The longleaf pine is superior wherever strength and durability are required. In tensile strength it approaches, and may surpass, cast iron. In cross-breaking strength it rivals the oaks, requiring 10,000 pounds per square inch on the average to break it, while in stiffness it is superior to the oak by from 50 to 100 per cent. It is best adapted for principal members of heavy construction, for naval architecture, for bridges, trestles, viaducts, and house building. The finer-grained, and especially the curly, timber is much sought for finishing wood. Its hardness fits it for planks and flooring, but unless quarter-sawed it is apt to "peel out." Being very resinous, it is sometimes difficult to handle in dry kilns, nor does it take paint readily; its hardness also makes it difficult to work, wearing out tools and muscles. The curly grained lumber, which is found quite frequently, makes an elegant finishing and furniture wood. It is an excellent fuel, and its resinous products supply the world with pitch, resin, and turpentine. Contrary to common belief, the tapping for turpentine was found, by a large number of tests lately made under direction of this division, not to weaken but to strengthen the timber in cross-breaking and compression and to increase its stiffness. (See full discussion in report on timber physics.)

The Cuban pine, mostly known locally as slash pine, is generally cut and sold without distinction from the longleaf, and its wood, if not superior in some respects, is probably not inferior in any to the latter, except as far as its coarser grain and larger amount of sapwood may influence

its usefulness. The tests of the Tenth Census would make its mechanical properties even superior to those of the longleaf.

The shortleaf pine, comparatively free from resinous matter, softer, capable of good finish, and more easily worked, furnishes a lumber better adapted to the use of the joiner, cabinetmaker, and carpenter than the other two. There being more sapwood in the log-run lumber and greater variation in its growth, more need for grading exists.

Until within two decades or so this lumber did not find ready market outside of its home, because the sapwood was apt to "blue;" but with the dry kiln these objections have been overcome, and it now finds wide application for lighter framework, weatherboarding (taking paint more readily than the longleaf pine), for flooring, ceiling, wainscoting, window casings, and sash and doors, and for shingles. It is also adapted for building of railroad cars and manufacture of furniture. In cross-breaking strength it is at least 25 per cent weaker than the longleaf, although occasional sticks are found as strong. In stiffness the difference is not so great on the average, but the best stick so far tested falls 20 per cent below the best longleaf. In shearing strength, however, it seems to equal the latter, showing that, although weaker, its cell elements are as firmly knit together.

The loblolly pine varies still more greatly in quality than the shortleaf pine, growing as it does under the most varied conditions. Hence opinions as to its value vary widely, and its usefulness is but imperfectly understood, except perhaps in some parts of its home, like lower Virginia, where most of the houses were built of this pine. Grown slowly on the poorer or wetter soils, at higher elevations and in a more northern climate, it produces more heartwood and better quality, while the rank growth on better soils presents a sappy, light, coarse-grained wood, soft, and quick to decay. In North Carolina, where it occupies the swamp borders, the variety, or rather the "quality," known as "rosemary" or "slash" pine, now nearly exhausted, furnishes a timber from long and large old trees in no way inferior to the shortleaf, which it closely resembles, and approaching even the longleaf.

Strength and durability it does not possess in great measure, but, properly seasoned, it furnishes a timber suitable for many purposes. Yet the timber tested from north Alabama seems to equal, if not surpass, in strength and stiffness the shortleaf from the same region. It is perfectly suited for rough work, joists and scantling, studding, and common boards, and about 75 per cent of the material for this purpose used in the markets of Baltimore and Washington comes from this pine, and the bulk is sawed in Caroline County, Va. Much is also used in Philadelphia. The best grades are selected for flooring, siding, and inside finish, although its liability to shrink, unless thoroughly seasoned, makes the propriety of this use doubtful. As cord wood it reaches also more northern markets (New York), and where a brisk flame with quick heat is desired, as in bakeries, brickyards, and potteries, it is very good. The name under which this lumber goes is Virginia pine, although I have found builders calling it "yellow pine" and "North Carolina" pine. Since this pine is of rapid growth, quickly occupying old abandoned fields and making saw logs in fifty years, it promises to become one of the prominent staples of our lumber market.

In North Carolina only the better quality is cut and sold indiscriminately with the shortleaf as "North Carolina" pine, while in the Gulf States east of the Mississippi but little is cut, and that only on special orders for inferior work (except in north Alabama). In Texas, however, where this pine abounds in perfection, 25 and more per cent of the lumber handled is loblolly, although at Beaumont, the principal point of lumber production, but little of this material was found at the mills. In Arkansas it is called "longleaf pine," and some Northern lumber yards which must have longleaf pine from Arkansas seem to supply themselves with this material. It is tapped for turpentine wherever found in the turpentine orchard, yielding a more fluid resin than the longleaf pine.

A fuller statement of the quality of the wood of these pines will be found in another part of this report.

Use of Wood.

In its use the wood of all four species is applied much alike. The coarse-grained, heavy, resinous forms are especially suited for timbers and dimension stuff; while the fine-grained wood, whatever species it may come from, is used for a great variety of finishing purposes.

Formerly these pines, except for local and house use, were mostly cut or hewn into timbers, but now especially since the introduction of dry kilns, Southern pine is cut into every form and grade of lumber. Nevertheless a large proportion of the total cut, especially of the longleaf pine, is still sawed to order in sizes above 6 by 6 inches and lengths above 20 feet for timbers, for which the longleaf and Cuban pine furnish the ideal materials.

The resinous conditions of these two pines make them also most desirable for railway ties of lasting quality.

Since the custom of painting and graining woodwork has given way to natural grain with oil finish, the wood of these hard pines is becoming very popular for inside finish.

Kiln-drying is successfully practiced with all four species, but especially with the Shortleaf and Loblolly pines which, if not artificially seasoned, are liable to "blue." The wood can be dried without great injury at high temperatures.

Growth and Development.

LONGLEAF PINE.

In a fruitful year, before the close of the season, with the advent of spring, a dry and sunny state of the atmosphere favoring the fall of the seed, the seedlings are found to come up abundantly in every opening of the forest where the rays of the sun strike the dry ground. The lower (hypocotyledonary) part of the axis of the plantlet is close to the ground, with eight to ten erect cotyledons from 1 to 1½ inches in length, their tips inclosed in the shell of the seed, with the long wing persistent and borne banner-like at the top of the plantlet. (See Pl. X, *a*.) The elongation of the ascending axis proceeds slowly, growth in length being retarded until a certain thickness has been attained, resembling in this respect the growth of the stem of endogenous trees.

Upon examination of a seedling in the latter part of April the cotyledons had disappeared and the caulicle was found to be from one-eighth to one-fourth of an inch long, its length not exceeding its diameter, hidden by a dense tuft of the needle-shaped primary leaves, which closely invest the terminal bud. At this stage a few fascicles of secondary leaves are already showing themselves, still inclosed in their sheaths.

During the first three or four years its energy of growth is mainly expended upon the development of its powerful root system. (See Pl. X, *c*.) Before the first spring season has passed, the stout spindle-shaped taproot of the seedling is found to be over 3 inches in length and provided with several fine lateral rootlets, sometimes nearly as long as the main root.

With the opening of June the primary leaves covering the axis are nearly all withered, only a few remaining to the end of the season. With the development of the suppressed secondary axes from which the foliage leaves proceed, the primary leaves are reduced to chaffy fimbriate bracts. Only a few of these primary leaves retain the needle-shaped form and green color, namely, those from which no leaf-bearing branchlets were developed. During the first season many of the fascicles of the foliage leaves contain only two leaves, and sheaths inclosing only one leaf are frequently observed.

By the end of the first year the stem of the plantlet is rarely over three-fourths of an inch in length, the main root having attained a length of from 8 to 10 inches.

Having reached the end of the second year the taproot is found from 2 to 3 feet in length, the stem scarcely 1½ inches long, with an increase of diameter hardly perceptible. The conical termination of the spring shoot is now densely covered with the delicately fringed bracts inclosing the buds of the foliage leaves, which impart to it the appearance of a silvery white tuft, by which this species is recognized at first sight.

During the following two years the growth proceeds but slowly, the length by the end of the fourth year averaging not more than 5 inches with a thickness of three-fourths to seven-eighths of an inch. During the same time the taproot is found to gain constantly both in thickness and length. (See Pl. X, *c*.) A few single branches now make their appearance on the main axis. The increase of growth from one season to another up to the seventh or eighth year is difficult to follow, since the difference in the appearance of the spring and summer wood cells in the spongy wood of young trees is hardly perceptible, and the rings of annual growth, even as seen in cross sections prepared for microscopical examination, are mostly too indistinct to afford a safe criterion

LONGLEAF PINE (PINUS PALUSTRIS) TYPICAL TREE.

PINUS PALUSTRIS: SEEDLINGS AND YOUNG PLANT.

a, germinating seed; *b*, young seedling just unfolded; *c*, seedling unfolding primary leaves; *d*, foliage leaves at end of season; *e*, young tree, 3 to 4 years old; one-third natural size.

of their age. As far as could be observed the growth proceeds equally slowly during the fifth and sixth years, the plant at the end of that period being from 5 to 7 or 7½ inches in length.

Stage of rapid growth.—With its seventh year the tree may be said to enter on its most vigorous growth. Henceforth the stem (primary axis) increases rapidly in length, and the development of branches (lateral axes) proceeds at an equal rate in regular whorls, to which the symmetry of the tree in that stage of its development is due. During the seventh year, generally, the tree doubles its length, and during a number of successive years the rate of growth in that direction varies between 10 and 20 inches annually, as is clearly shown by the length of the internodes separating the whorls. As the branches increase in length they produce, in the same order mostly, two opposite secondary branches. With the rapid expansion of the leaf surface, the formation of wood keeps pace. The rate of growth in diameter, as well as in height, during this period is, of course, variable according to differences in the physical condition of the soil, as well as in the available amount of plant food and moisture it contains, and no less upon differences in temperature and of exposure to light and air.

When the tree has reached its second decade it begins to produce flowers and fruit. Having during the course of the following fifteen years reached a length of from 40 to 45 feet, with the main stem clear of limbs, the growth of branches does not proceed with the same regularity; consequently they are no longer arranged in regular whorls, but appear irregularly, and thus the symmetry of the tree is lost.

Stage of slow growth.—Rapid as is the increase in length of the primary axis or trunk, amounting during the first half century, in the average, to 14 or 15 inches annually, the rate is subsequently greatly diminished, averaging from the fiftieth to about the one hundred and fifteenth year but from 4 to 5 inches, and from this time to the age of two hundred and fifty years only 1½ inches—that is, at a relative rate of 10, 3, and 1 in the three successive periods. The decrease in the accretion of wood corresponds with the reduction in the growth of the branches and consequent reduction of foliage. From what has been said, it is seen that the longleaf pine attains maturity of growth, with the best qualities of its timber, at an age of from one hundred and eighty to two hundred years. After having passed the second century the trees are found frequently to be wind shaken and otherwise defective. The deterioration of the weather-beaten crown lessens the vitality of the tree, and the soil, under prevailing conditions, becomes less and less favorable. In consequence, the trees become liable to disease and mostly fall prey to the attacks of parasitic fungi (red heart). Instances of trees which have reached the maximum age of two hundred and seventy-five or three hundred years are exceptional.

In order to ascertain the age required to furnish merchantable timber of first quality, measurements were made of a number of logs in a log camp in the rolling pine uplands of the lower division of the coastal pine belt near Lumberton, Washington County, Ala. From the results obtained it appears that in this section of the eastern Gulf region, at the lowest figure, two hundred years are requisite to produce logs of the dimensions at present cut at the sawmills.

Demands upon soil and climate.—In its demands upon the soil this pine is to be counted among the most frugal, as far as mineral constituents, which are considered as plant food, are concerned, if only the mechanical conditions which influence favorable soil moisture are not wanting. It thrives best on a light siliceous soil, loamy sand or pebbles or light sandy loam, with a slightly clayey subsoil sufficiently porous to insure at least a partial underdrainage and to permit unimpeded development of the long taproot. Whenever the tree meets an obstacle to the development of this root it remains more or less stunted.

The luxuriance of the growth and increase in size of the timber, however, is greatly influenced by the quantity of clay present, particularly in the deep subsoil, which improves mechanical and moisture conditions. This is strikingly exhibited in the timber of the level pine flats west of the Mississippi River, although the surface drainage is almost wanting and the underdrainage through the loamy strata slow, so that the surface of the soil remains damp or water-soaked for the greater part of the year; the stand of timber of first-class dimensions exceeds considerably that of the rolling pine uplands on the Atlantic slope and the lower part of the pine belt in the eastern Gulf region, which are poorer in clay. Evidently, although the underdrainage is less perfect, the moisture conditions during the dry season of the year, the time of most active growth, must be most favorable. The same fact is apparent in the upper part of the coast pine belt in

Alabama and Mississippi, where, upon the same area, with a smaller number of trees, the crop of timber may be considered almost twice as heavy as that found on the pine barrens proper farther south. On the soil of fine, closely compacted sand, entirely deficient in drainage as found in the so-called pine meadows along the coast of western Florida, Alabama, and Mississippi, as well as on the siliceous rocky ridges of central and northern Alabama, the tree is so stunted as to be of little or no value for its timber.

"It is neither temperature alone, nor rainfall and moisture conditions of the atmosphere alone, that influence tree growth, but the relation of these two climatic factors, which determines the amount of transpiration to be performed by the foliage, and again with most species we must place this transpiration movement into relation with available soil moisture, in order to determine what the requirements and the most suitable habitat of the species are" (B. E. Fernow). Hence we find that east of the Mississippi River the longleaf pine occurs in greatest frequency along the isotherm of 60° F. ranging to 34° north latitude, while west of the Mississippi it follows a line between the isotherms of 63° and 64° F. and is scarcely found north of the thirty-second parallel of north latitude. Within this area of its distribution it is exposed to wide variation of temperature and moisture conditions.

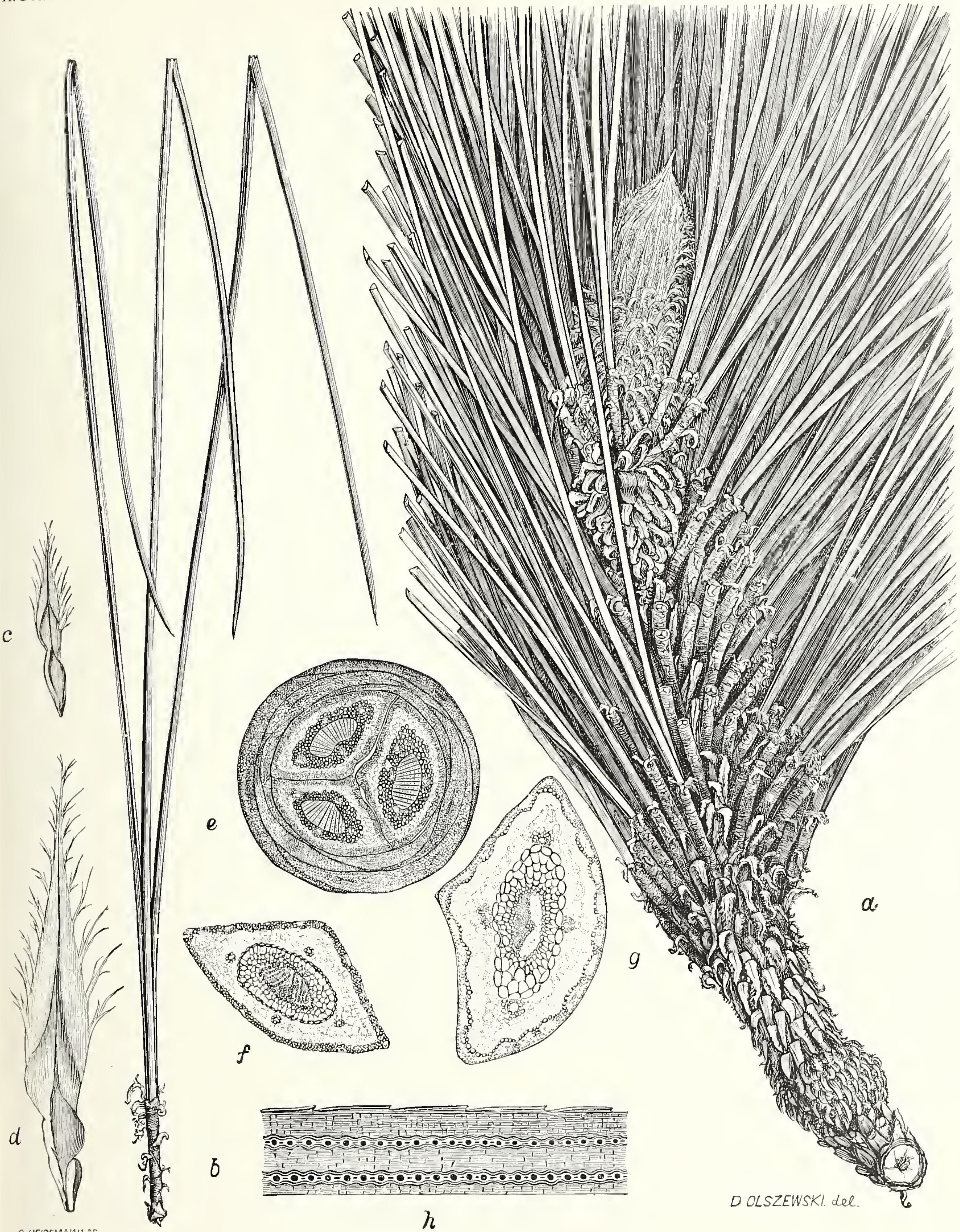
Under the influence of the vapor-laden breezes from the Mexican Gulf and an evenly distributed rainfall ranging from 42 to 63 inches during the year, the longleaf pine appears of the same thrift and vigor of growth in the interior of Alabama under 34° to 35° north latitude, with the thermometer falling as low as 4° F. (16° C.) and a range of temperatnre of 93° (at Tuscaloosa), as it is found in the subtropical belt of the coast with a maximum temperature of 105° F. (40° C.) and a range of temperature of 94° west of the Mississippi River, although the temperature reaches rarely a minimum of 15° and 12°, respectively, at the northern limit of the tree in these States, the diminished humidity of the atmosphere and lesser rainfall, particularly during the warmer season, account for its absence. There can be no doubt that the greater exposure to the violence of the sudden gusts of dry and cold wind known in Texas as "dry northers" exercises also no small influence in limiting the longleaf pine.

Associated species.—The longleaf pine is eminently a gregarious tree, covering areas of wide extent, to the almost complete exclusion of any other species. In the flat woods of the coastal plain, particularly near its northern limit on the Atlantic slope, it is not infrequently associated with the loblolly pine; farther south and along the Gulf coast to the Mississippi River, more or less frequently with this tree and the Cuban pine. In the upper part of the maritime pine belt it not rarely occurs together with the shortleaf pine and the loblolly pine intermixed with the deciduous trees of the uplands, viz, the black oak, Spanish oak, black-jack, bitternut, mockernut hickories, and black gum.

It will be apparent, from what has been said regarding the demands for light, that the associated species must be either slower growers or later comers, if the longleaf pine is to survive in the mixture. As has been pointed out elsewhere, with the culling of the longleaf pine from the mixed growths it must soon cease to play a part in them, since its renewal under the shade of the remaining associates is impossible.

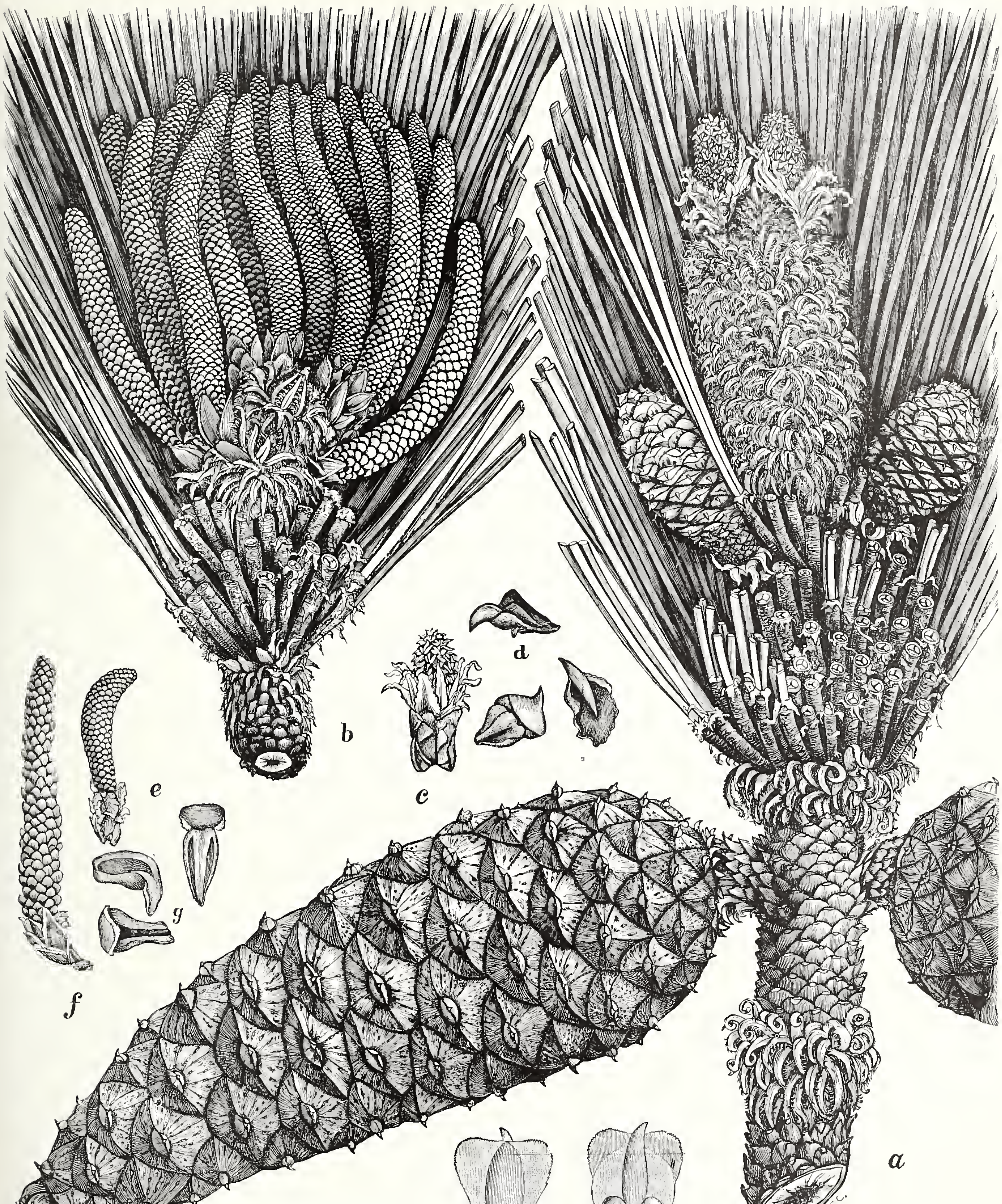
Enemies.—The greatest danger threatening the existence of the forests of longleaf pine must be ascribed to the agency of man, since their destruction is caused chiefly by the reckless manner in which they are depleted without heed to recuperation. The right of ownership has been generally acquired on such low terms that since no value has been attached to the land without the timber, despoliation has been carried on with no other object than the quickest return of pecuniary profits.

Exploitation.—Such management could not but entail tremendous waste, a large percentage of the body of the trees felled being left on the ground to rot or to serve as fuel for the conflagrations which scour these woods almost every year. Infinitely greater than the injuries inflicted upon the forest by the logger and by getting out cross-ties and hewn square timber, which consist chiefly in the accumulation of combustible waste, are those caused by the production of naval stores. When the fact is considered that the production of the 40,000 barrels of spirits of turpentine, which on an average during the latter half of this decade annually reached the market of Mobile alone, implies the devastation of about 70,000 acres of virgin forest, the destruction caused by this industry appears in its full enormity. Under the management of the turpentine orchards



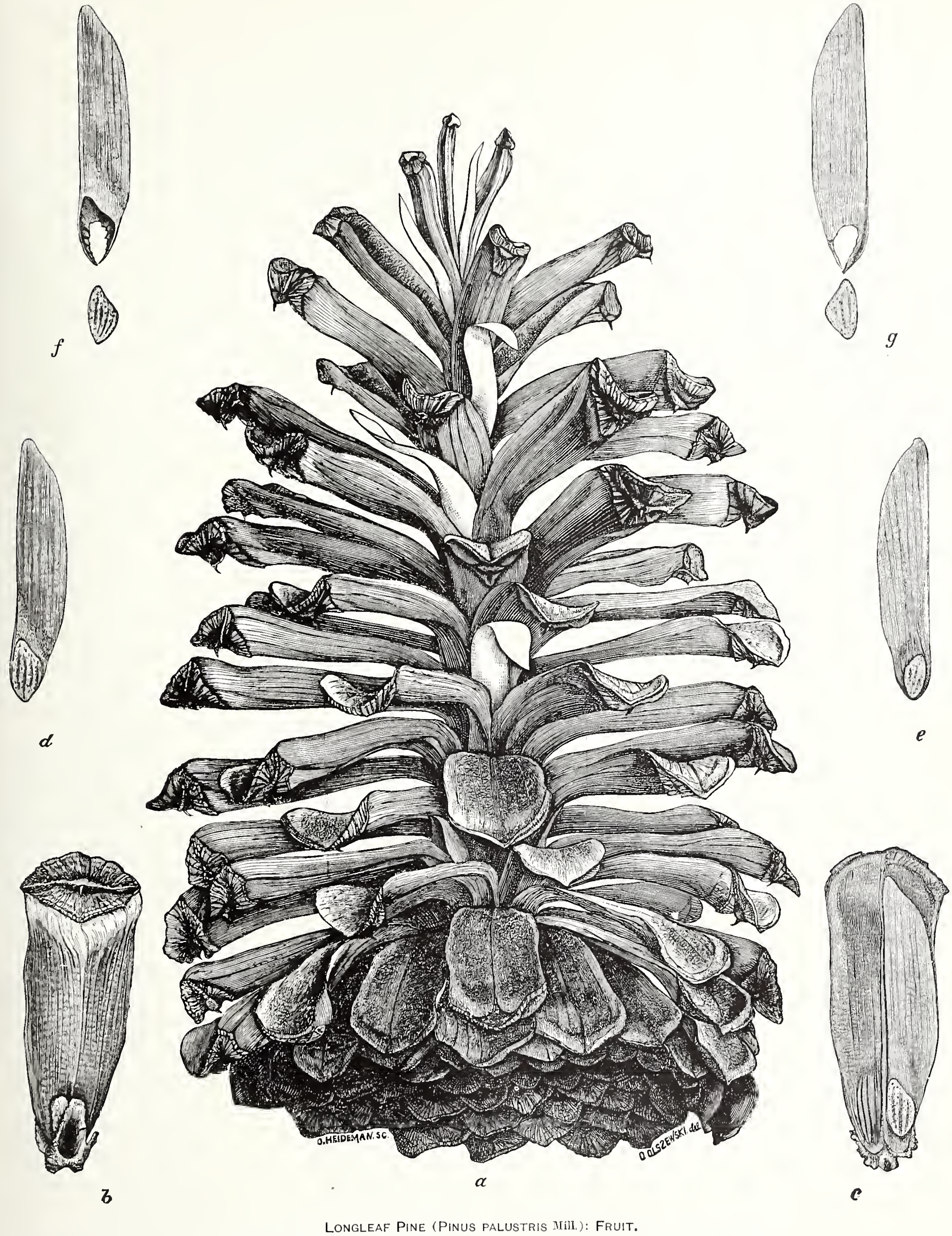
LONGLEAF PINE (PINUS PALUSTRIS Mill.): BUD AND LEAF.

a, branch with terminal bud; *b*, leaf bundle; *c*, *d*, primary leaf bracts (magnified); *e*, cross section through base of leaf bundle (magnified); *f*, *g*, cross sections (magnified) of leaves; *h*, longitudinal section through leaf.



LONGLEAF PINE (PINUS PALUSTRIS): MALE AND FEMALE FLOWERS.

a, fruiting branch with female aments at tip, and one and two seasons' cones; *b*, male aments; *c*, female ament; *d*, seed-bearing scales; *e*, *f*, male aments; *g*, detached anthers; *h*, *i*, detached female flowers.



LONGLEAF PINE (PINUS PALUSTRIS Mill.): FRUIT.

a, open cone, natural size; *b*, *c*, detached scales, dorsal and ventral; *d*, *e*, *f*, *g*, seeds with wings.

prevailing at present, trees of such small size are tapped that they are unable to resist the force of the winds, and in a few years are inevitably prostrated, while the larger trees, weakened by the severe gashes on almost every side, become largely wind-shaken and the timber after a few years almost worthless.

While a judicious tapping is not only justified, but demanded, by an economic system of exploitation, the prevailing methods of orcharding are unnecessarily destructive.

The tapping of sapling timber not yet ripe for the saw, and the destructive fires started in connection with this industry, annihilating all young growth, prevent any renewal of the forest, while the working of large bodies of timber years before milling facilities are available leads often to a loss of 20 per cent and more in both quality and quantity of the merchantable product.

Fires.—The greatest injury to which the pine forests are subject in consequence of turpentine orcharding arises from the fires which are started every spring for the purpose of getting rid of the combustible matter raked from around the tapped trees in order to protect them from accidental conflagrations while they are worked. These forest fires, spreading far beyond their intended limits, destroy entirely the youngest progeny of the pines, stunt the growth of the more advanced trees, and cause the ruin of a large number of older ones in the abandoned turpentine orchards. Burning deeply into the gashes and other exposed surfaces of the tapped trees, these fires hasten their prostration by the gales. Moreover, the fire causes cracks in the surfaces laid bare by the ax and the puller occasions greater exposure to atmospheric action, thus inducing more or less rapid decay. A test, made by sawing through twenty-two logs taken at random from a turpentine orchard after it had been abandoned for a period of sixteen to eighteen years, showed that about one-half of the timber was partially decayed and shaky.

Besides the production of naval stores as a cause of forest fires, there is another scarcely less potent. This is the practice prevailing among the settlers of burning the woods upon the approach of every spring in order to hasten the growth of grass for their famished stock. Fires are also frequently started through the carelessness of loggers and hunters, in the preparation of the ground for tillage, and by sparks from locomotives. These fires, occurring at least once during every year, cause the total destruction of the young growth of the longleaf pine. The danger to this species is much greater than to any other Southern wood, because of the greater length of time it requires to reach a size at which it can offer some resistance to fire. In the open forest of longleaf pine the fires are not so destructive to the larger timber as in the dense forests of coniferous trees further north, trees of larger size being, with some exceptions, but slightly, if at all, directly damaged.

Another serious damage, however, resulting from the frequent recurrence of fires is the destruction of all vegetable matter in the soil. Deprived of the mulching needed for the retention of moisture, the naturally porous and dry soil, now rendered absolutely arid and barren, is no longer capable of supporting any larger tree growth or other useful vegetation.

Live stock.—Of no less danger to the existence of the forests of longleaf pine is the injury caused by live stock. This agency, slow in its action, is sure to lead to their destruction unless restricted to some extent. Beside the damage due to the trampling down and mutilation of the young growth by herds of cattle roaming through the woods, the smaller domestic animals—goats and sheep—eat the tufts of the tender foliage of the seedlings, while hogs are seen digging up and chewing the spongy and tender roots of the young plants. As a further agency in the way of the renewal of this species, the destruction of the mature cones might be mentioned, caused principally by the squirrels, which peel off the scales clean to the core in search of the sweet, nutritious seed.

Storms.—Full-grown trees are frequently uprooted by the hurricanes which from time to time pass through the pine belt. Those having the taproot shortened by impenetrable layers of indurated clay, interposed in the subsoil at varying depths, are invariably the first victims of the high winds. In trees grown in such places the taproot is found with a tumid and round base as smooth as if polished.

CUBAN PINE.

This is the earliest flowering of the Southern pines. The buds of the male flowers make their appearance in the early part of December, and the flowers open during the last days of January and during the first week of February. This species produces abundant crops of cones every year,

almost without failure; they ripen in the fall of the second year; the seeds are discharged through the winter of the second year until spring. Germinating easily, their seedlings are found to come up copiously from early in the spring to the beginning of the summer in old fields and on every opening in the vicinity of the parent trees, wherever the rays of the sun reach the ground. The plantlets bear six to seven seed-leaves (cotyledons). As soon as these have fairly expanded the terminal bud develops rapidly, and the first internode of the stem, increasing quickly in length, is densely covered with the soft, narrow, linear, pointed, primary leaves, which are fully an inch long. Before the end of the second month, in the axils of some of the leaves, the undeveloped branchlets, bearing the fascicle of the foliage leaves, make their appearance. With the further development of the foliage leaves, increasing in number during the growing season, the primary leaves wither away. By the close of the first season the plantlets are from 8 to 9 inches high, with a very slender taproot and many lateral rootlets near its upper end. After the beginning of the second season but few of the primary leaves are found to support the buds of the foliage leaves. The tendency to the production of secondary axes becomes manifest by the appearance of a single branchlet; on having reached the end of their second year the plants are from 12 to 15 inches high, with a taproot not more than 4 inches long; at the end of their third year they average little less than 2 feet in height, with the taproot 6 inches long—the laterals being much longer. The crown from this period develops in regular whorls for a long succession of years.

The Cuban pine, in its rate of growth and when fully grown, exceeds in its dimensions the longleaf pine. The taproot, less powerful than in its allies, is assisted by mighty lateral roots running near the surface of the ground to support the tall, sturdy trunk, rising to a height of 110 or 115 feet, with a diameter of 2½, not unfrequently exceeding 3, feet, clear of limbs for a height of from 60 to 70 feet above the ground. The heavy limbs are horizontally spreading, from 22 to 24 feet at their greatest length, somewhat irregularly disposed; they form in the trees of full growth a rather dense crown of rounded outline. Trees of the dimensions mentioned, having passed the fullness of their growth, are found to be from one hundred to one hundred and forty years old, according to the surrounding conditions. The thick bark is of a clear, reddish color, laminated, and exfoliating in thin, broad, purplish flakes.

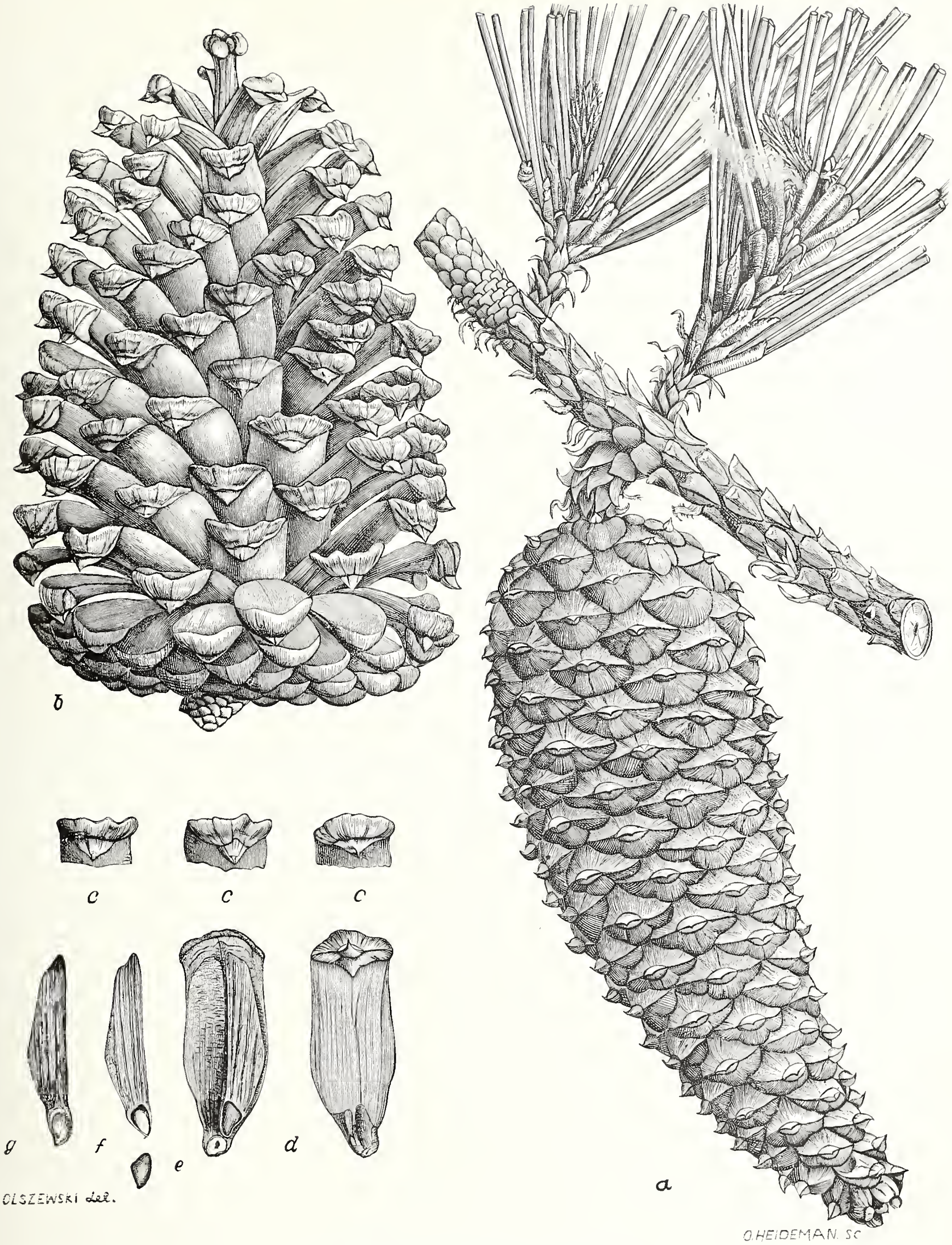
Seedlings of the longleaf pine, which those of the Cuban pine somewhat resemble, can be readily distinguished at this period by the disproportion of height and diameter and absence of branch growth in the former. The rate of growth differs, of course, according to the conditions of soil and exposure.

Saplings showing five rings of annual growth were found from 4½ to nearly 6 feet in height, with a diameter of from three-fourths to seven-eighths of an inch; between the age of from ten to twelve years the trees measure from 10 to 18 feet in height, with the stem clear for over half its length—even when grown in the open—and from 2 up to 4 inches in diameter. From this stage on the rate of growth proceeds most rapidly. At eighteen and twenty years heights of 40 to 50 feet and over, and diameters from 9 to 10 inches across the stump, cut close to the ground, are attained.

Soil.—For its best development the Cuban pine requires a light, sandy, but constantly damp soil, which is attained where the sandy surface is underlaid by a loamy subsoil retentive of moisture but sufficiently loose to give the roots unhindered access. Such conditions are found on the lands rising above the perpetually wet swamps. On the flats, with a soil of fine, compact sand, devoid of all drainage and underlaid by a hardpan, where nothing but the saw palmetto appears to thrive, the tree remains of low, stunted growth, scarcely ever reaching medium size. In the depth of the swamp, with the soil wet and slushy throughout the year, where the tree is commonly met with, closely surrounded by white bay, red bay, black gum, titi, and white cedar towering high above it, it is of slow growth and frequently affected by red heart or red rot, particularly near its northern limit. It is never found in alluvial bottoms, and eschews the dry, pine-barren hills, requiring a moderate but sure and even supply of soil moisture.

Climate.—The range of its distribution coincides with the area of greatest rainfall in the Southern States, which, evenly distributed through all seasons, amounts for the year, in the mean, to 60 and 64 inches.

The Cuban pine demands a warm climate, free from excesses in the range of temperature, as is afforded by the vicinity of the sea. It is found in greatest abundance and most perfect within



CUBAN PINE (PINUS HETEROPHYLLA (Ell.) Sudw.).

a, closed cone; *b*, open cone; *c*, apophyses; *d*, cone scales, dorsal and ventral view; *e*, *f*, *g*, seed and seed wings, dorsal and ventral view

the isothermal lines of 64° and 68° F., with a minimum of but a few degrees below the freezing point. The tree, as observed at Mobile, has escaped uninjured the severe and unprecedented long spell of ice and snow during the latter part of January and first week of February, 1895, when the thermometer fell as low as 11° F., the flowers unfolding unimpaired by frost during the succeeding first days of milder weather.

In its dependence on light it is less exacting than either the longleaf pine or the loblolly pine. It appears to thrive, from the earliest stage of its development, as well when partially shaded as in the open, in this respect resembling the Southern spruce pine. It is due to these facts, combined with the rapid progress of its growth from the earliest stage, that the Cuban pine is gaining the upper hand over the offspring of the light-requiring longleaf pine, which, on the damp soil of the coast plain, is soon outstripped and finally almost completely suppressed by the seedlings of this tree.

In the inherent capacity for natural reproduction, or in the advantages for the renewal of its forests by man, the Cuban pine is not surpassed by any other of the species with which it is found associated. This tree commends itself strongly to the tree planter in the coast plain of the lower South. Producing seeds in abundance regularly and with certainty, being less exacting in its demands for direct sunlight, and hence successfully resisting the encroachment of competing species, being less liable to succumb to the destructive agencies of fire on account of its more rapid development in early life, it has greater promise of success than the others. If to this is added the rapid rate of growth, the great value of its timber, being equal to the longleaf, if not superior, and the abundant yield of its valuable resinous product, it becomes evident that in the reforestation of the low pine lands of the Southern coast region the Cuban pine is to be preferred to any other, not only within its original boundaries, but as far beyond its range of natural distribution as the climatic requirements of the tree will permit.

SHORTLEAF PINE.

The seeds begin to swell and to germinate in the early days of spring. In Mobile County, on the end of the first week of March, the plantlets had their cotyledons fully unfolded, which were found to vary from six to seven in number, with the lower (hypocotyledonary) part of the axis from 1½ to 2 inches long, the rootlets being somewhat less in length (Pl. XVI, *e*, *g*). The development of the upper part of the axis (caulicle) from the terminal budlet and of the primary acerose leaves proceeds now rapidly. These primary leaves succeeding the cotyledons are stiff and spreading, about three-fourths of an inch long and covering the stem densely (Pl. XVI, *g*), remain during the first season, withering from below during the warmer part of the season. By the close of the first season the caulicle or first shoot has attained a length of from 3 to 4 inches. On the shoot of the second season (rarely before) the secondary leaves, which constitute the foliage, make their appearance from the undeveloped branchlets in the axis of the primary leaves (Pl. XVI, *g*). At the end of the second year the plants are 7 to 8 inches high, with a taproot 2 to 3 inches long. During this season adventitious buds appear at the collar of the stem, which bring forth vigorous sprouts, particularly if the stem has sustained the slightest injury. These shoots are covered with primary leaves, which are retained for one season. They are apt to form strong branches before the tree has reached its fourth or fifth year; such branches, which are produced profusely from the stumps of larger trees, scarcely survive another season. It is rarely that branches are produced in the second year, the first branches appearing generally in the third season in whorls of three to four. In the third year foliage leaves alone are produced in the axils of scales with their bases close to the stem. At the close of the third year the plants are from 12 to 18 inches high. Now the development of the root system advances rapidly, the taproot being by this time about 8 or 10 inches long, with strong lateral roots often double that length. Both taproot and lateral roots are finally vigorously developed, penetrating deep into the ground, so that trees of this species are rarely blown down by winds. At the end of the fourth year the plants are from 2 to 3 feet high, with the stem at best from five-eighths to seven-eighths of an inch thick.

The branches of the whorls begin now in their turn to develop branchlets in whorls of secondary order. The development of the primary axis and its branch system proceeds henceforth in the regular acropetal order. As in all pines, the shoot of the main axis takes the lead in rapidity and

vigor of growth. By a number of measurements made at Cullman, north Alabama, of trees from the openings in the forest, as well as from clearings, it was found that by the end of the fifth year they had attained a height varying between 3 and 5 feet, rarely over, the stem being from five-eighths to seven-eighths of an inch in thickness; by the end of the sixth year, from 6 to 9 feet high and from one-half to 2 inches in diameter; and at the tenth year, from 10 to 16 feet high and from 2 to $2\frac{1}{2}$ inches in diameter. At the age of fifteen to twenty years, with a total height of from 20 to 30 feet and a diameter, breast high, of 4 to 5 inches, the crown of the tree occupies from one-half to five-eighths of its height. Henceforth throughout the period of quickest growth its rate is greatly influenced by conditions of light and soil. At the age of fifty years the height of the trees varies between 40 and 60 feet and the diameter, breast high, between 10 and 14 inches. About this age, or perhaps a short time before, the height growth begins to decline and the branches become somewhat reclining below and spreading toward the top, and consequently the head of the tree becomes more rounded in outline. Between the ages of sixty and seventy years the trees are from 50 to 70 feet high and from 12 to 15 inches in diameter, with the trunk clear of limbs for 30 to rarely over 40 feet. From this period on the growth proceeds at a slower rate. On reaching its one hundredth year the tree has attained a height between 90 and 95 feet and a diameter of from 16 to 19 inches at most. Having now passed its period of vigorous life, the growth is henceforth insignificant. Between the ages of one hundred and twenty and one hundred and thirty years trees were found 90 to 110 feet high and from 18 to 24 inches in diameter. The oldest tree encountered in the measurements, with two hundred and eight rings of annual growth in the stump, scarcely exceeded 109 feet in height and measured 24 inches in diameter. The largest tree felled was 117 feet high and 25 inches in diameter, with one hundred and forty-three rings in the stump. Occasionally trees are found of a diameter exceeding 3 feet, but such are exceptional.

Soil and climate.—The shortleaf pine prefers a well-drained, light sandy or gravelly clay soil or warm loam, even if deficient in the elements of plant food. Soils of this character which are found widely prevailing over the undulating or broken uplands, if only of sufficient depth, will produce this tree in greatest perfection. It avoids the strongly calcareous and the rich alluvial soils, as well as purely siliceous, being dependent on the presence of a certain amount of clay by which the mechanical condition of the soil is improved, rendering it more compact and more retentive of moisture. That a purely sandy and highly porous soil is not favorable to this tree is shown by the stunted growth of the waifs sometimes found in the openings of the forests of longleaf pine on the sandy, arid uplands in the lower part of the coast pine belt.

Distributed in its range over 10 degrees of latitude and exposed to wide differences of temperature, it shows almost the same thrift of growth near its northern limits under the isotherm of 50° F. and in regions where the thermometer falls to near 20° below zero as in lower latitudes with a mean annual temperature of 64° F. It can, therefore, endure a considerable range of temperature.

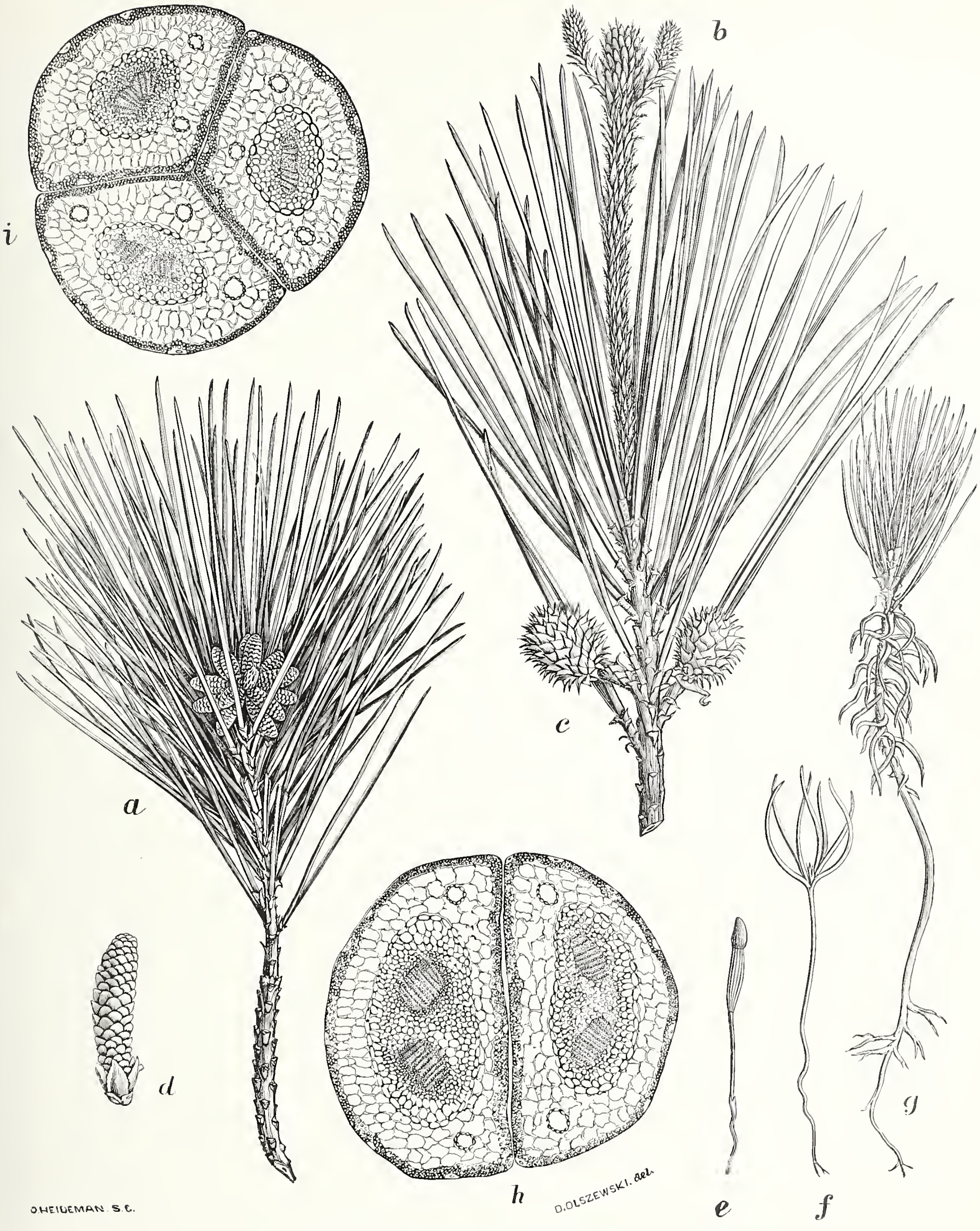
The conditions of atmospheric moisture evidently exercise a much more decided influence over its distribution, and, without doubt, upon its individual development. The tree is found in greatest abundance and of best growth where, within the limits of its distribution, the annual rainfall varies between 48 to 52 inches, is less frequent in the districts where the precipitation exceeds 56 inches, still scarcer where the annual rainfall averages below 44 inches, and entirely wanting where this is less than 40 inches. Hence it is found best developed in the upper part of the Gulf States and west of the Mississippi River in adjacent northern districts from the interior of Georgia to northeastern Texas, where the most favorable conditions in regard to atmospheric precipitation prevail. The tree seems to avoid the humid air of the coast along the Gulf, as well as along the seashore of the Southern Atlantic States, nor does it ascend the mountains in these States above an altitude of 2,500 feet.

Relation to light and associated species.—The shortleaf pine, like most pines, is a light-needing species, being, however, less sensitive to a deficiency in this direction than the longleaf and Cuban pines, which latter succumb in competition with the shortleaf pine. Originally the shortleaf pine is found more or less associated with various oaks (Spanish oak, blackjack, scarlet oak, post oak, and black oak), the mockernut and the pignut hickory, and more rarely with the chestnut, the mountain oak, and the scrub pine. All of these species prefer the warm, lighter soils of the uplands. These companions of the shortleaf pine are joined in the lower Southern States by

SHORTLEAF PINE (PINUS ECHINATA), FOREST-GROWN SPECIMENS IN MISSOURI.

SHORTLEAF PINE (PINUS ECHINATA Mill.).

Cone, seed, and leaves.



SHORTLEAF PINE (PINUS ECHINATA Mill.),

a, branch with male aments; *b*, branch with female aments at tip and one season's cones at *c*; *d*, male flowers; *e*, *f*, *g*, development of seedling; *h*, *i*, sections through leaf bundle.

the loblolly and longleaf pine. Wherever in these upland forests an opening is made the shortleaf pine gains over its associates, finding its only successful rival in the loblolly pine. It is in the Southern States proverbial that in the upland forests "the pine is crowding out the hard-wood timber," a fact early observed. The displacement is effected either gradually in the course of time, or instantly when the removal of the original timber growth has been sudden. In the upper part of the maritime pine belt, where it is associated with the longleaf pine, the latter is sure to be replaced by the shortleaf species, often joined in the course of such invasion by the loblolly pine.

LOBLOLLY PINE.

The crops of seed are produced quite abundantly every year and copiously dispersed over the vicinity of the mother trees by the wind, the offspring quickly taking possession of old fields and clearings in the forest.

The seeds germinate in the early spring. The ends of the cotyledons remain for a short time after germination inclosed in the endosperm. The number of the germinal leaves (cotyledons) is mostly six, rarely seven. At the time of the unfolding of the cotyledons the lower (hypocotyledonary) part of the axis of the plant is about 1 inch in length. The rootlets are half that length, and are provided with several acropetal secondary rootlets. The caulicle grows rapidly, and is soon covered with the stiff, needle-shaped, and strongly serrulated primary leaves. Before the spring season has passed the bundles of secondary or foliage leaves make their appearance in the axils of the former. At the close of the summer season the plantlet has attained a height of from 6 to 8 inches, the upper part of the stem covered with foliage leaves, the acerose primary leaves of the lower part having completely withered. In examining a large number of young plants never less than three leaves in a bundle have been found during this or any subsequent stage of the growth. With the second year the primary leaves have all become reduced to the ordinary form of the leaf bract—lanceolate, acuminate, with fimbriate white hyaline edges and tips.

In all the specimens examined it was found that the growth of the main axis proceeded less rapidly during the second season, but produced a regular whorl of from three to four lateral axes. At the close of the second year the main stem rarely exceeds 10 inches in height.

At the end of their third year the plants are from 18 to 20 inches high, the stem being from one-fourth to five-sixteenths of an inch in thickness. The branches, forming regular whorls, are erect and produce in their turn whorls of secondary order. The root system shows a corresponding increase, the taproot being from 6 to 8 inches long, with numerous stout lateral roots.

With the fourth year the loblolly pine enters seemingly upon the period of quickest growth. As ascertained by many measurements, the trees at the end of their fourth year average 3 feet in height and from one-half to seven-eighths of an inch in diameter, and at the end of the fifth year measure nearly 5 feet and from 1 to $1\frac{1}{4}$ inches in diameter. At the beginning of the seventh year the tree attains a height of 10 feet, and with the close of the first decade trees are found 12 to 16 feet high and from $2\frac{3}{4}$ to 3 inches in diameter. Some trees begin to mature their first cones by the tenth year.

The above measurements were made in 1890 in the vicinity of Cullman, Ala., on trees taken indiscriminately from the midst and near the border of a dense pine thicket covering a field plowed for the last time in 1882, and from an adjoining opening in the forest protected from fire and but rarely used for pasture.

According to a number of measurements made of trees in the southern Atlantic States, the Gulf region, and southern Arkansas, the loblolly pine reaches at the tenth year, on the average, a height of 20 feet, doubling this height during the succeeding decade. During this period of quickest growth the increase in height proceeds at the rate of 2 feet per annum, and trees twenty years old average $4\frac{1}{2}$ inches in diameter breast high. At the age of fifty years the trees are from 65 to 75 feet in height (average about 70 feet) and 15 inches in diameter breast high. The annual increase for this period of thirty years is about 1 foot in height and 0.35 inch in diameter. From numerous observations it appears that the loblolly pine attains the fullness of its growth at the age of one hundred years, with a height, on the average, of 110 feet and a diameter breast high of 2 feet, the length of merchantable timber varying between 50 and 60 feet. The annual rate of height growth during the second half century is about eight-tenths of a foot, and the diameter

growth eighteen one-hundredths of an inch. Henceforth the growth in height remains almost stationary. A dozen trees from one hundred to one hundred and fifty years old were found to vary from 99 to 125 feet in height, with a length of trunk free from limbs of from 60 to 68 feet and from 19 to 27 inches in diameter at breast height.

From tabulated records of growth it becomes evident that under similar conditions of soil and exposure the rate of increase for the various stages of growth show but slight differences in localities widely distant from each other.

Soil and climate.—The loblolly pine prefers a moist, cool, sandy, or light loamy soil, which if not always moist, should have greater retentiveness for moisture than is required by most of the other upland pines. It reaches its greatest perfection in the perpetually moist or fresh forest lands with a soil of a sandy loam, rich in vegetable mold which border the swamps of the coast region. The tree is not found on the porous highly silicious soils of the more elevated uplands, where the longleaf pine almost exclusively prevails. It also avoids heavy clay and calcareous soils of the uplands and the alluvial lands.

The loblolly pine is a tree of austral regions confined to the humid belt of the austro riparian or Louisianian zone and the lower border of the Carolinian life zone, which on the Atlantic coast follows quite closely the isothermal line of 56° F.; westward, in the direction of the Gulf coast, the isothermal line of 60°. The mean temperature of the winter along the northern limit is about 45°, with the lowest temperature only occasionally falling below 10° F. This tree approaches the Appalachian zone only under the influence of a peninsular clime between the Delaware and Chesapeake bays.

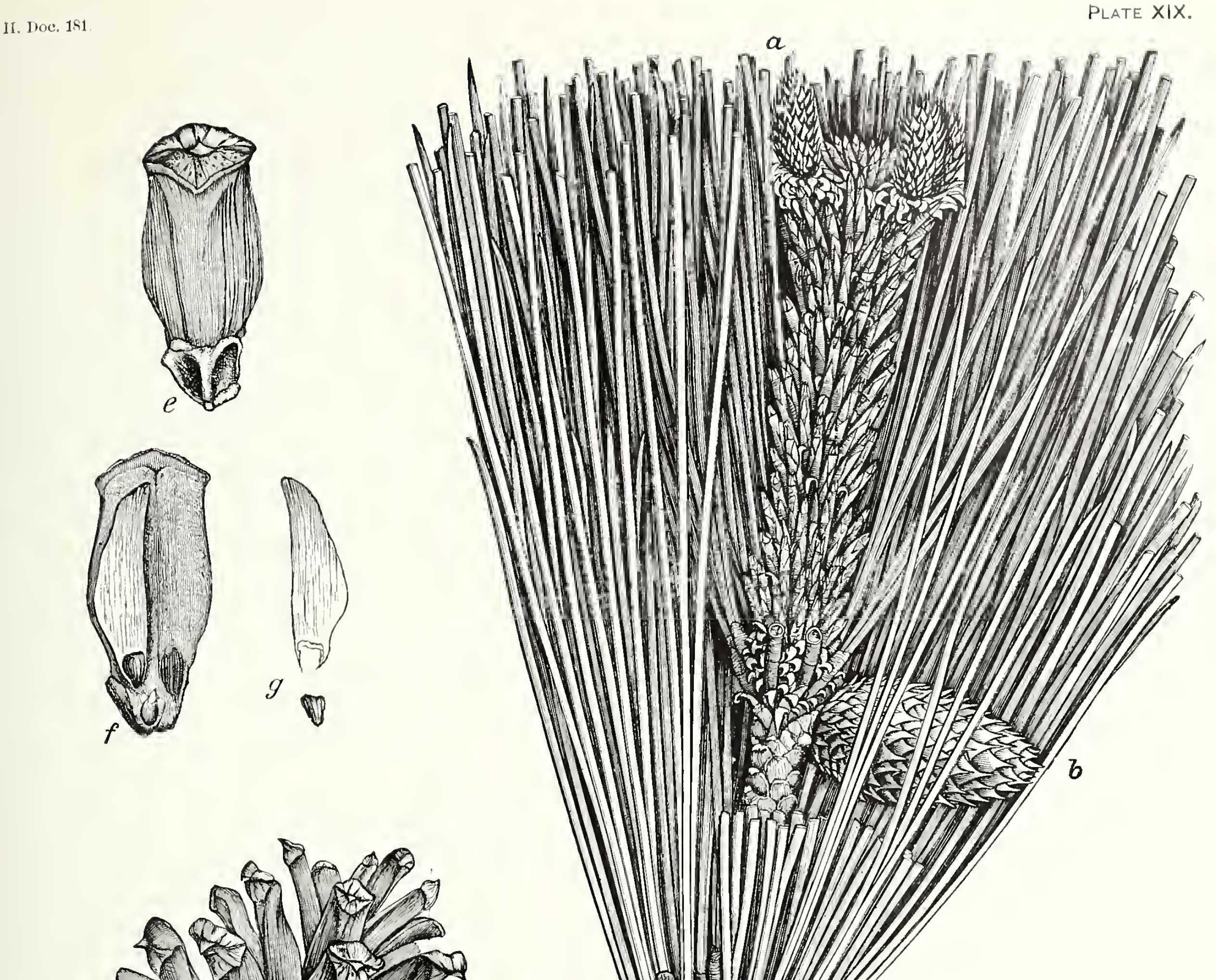
The loblolly appears to be indifferent to the wide differences in the amount of atmospheric precipitation existing within the vast range of its distribution. Extending from Florida (isotherm, 70°) to the thirty-ninth degree of north latitude on the Atlantic coast (isotherm, 56°), it is found of equal thrift on the Gulf shore, with its damp air and annual rainfall exceeding 64 inches, and in the flat woods of Texas, where the mean annual precipitation is only one-half that amount, with a mean of 6 inches during the winter months. In fact, the loblolly pine is found most frequently and is more widely distributed in the districts of lesser precipitation. It is certainly more dependent on the supplies of soil moisture than upon atmospheric humidity.

Relation to light and associated species.—This species is less exacting in its demands for direct sunlight than the kindred species within its range. To this relation may be ascribed the success which it achieves in the struggle for the possession of the soil with the shortleaf pine. Observing this contest as it is going on between the competing species in the forest, the conditions of the soil being equally favorable, the loblolly pine, under the cover of shade, outstrips the shortleaf pine under the same conditions; and, on the other hand, where the sunlight has had unhindered access, it gives way to its competitor, being then subjected to the disadvantage resulting from a speedier desiccation of the soil. Through such influences it is that, under conditions seemingly equally favorable to either one of these pines, now the one and now the other is found to predominate.

In the deep forests covering the rich swampy lands of the coast regions, the loblolly pine forms comparatively a small part of the rich and varied growth consisting chiefly of deciduous trees, black gum, sweet or red gum, water oak, and mockernut, to which in the lower South the magnolia, sweet bay, red bay, and Cuban pine are to be added. Although requiring less sunlight than most pines, in the gloomy impenetrable shade of these dense forests the progeny of the loblolly pine has no future, especially as these lands once cleared are devoted to tillage, being of great agricultural value.

On the lands of a poorer, more exposed soil in the maritime plain of the southern Atlantic States, in Virginia and North Carolina, and in southwestern Texas, this pine forms more or less compact forests. In these forests the tree is always succeeded by its own progeny, either in the course of nature or after the artificial removal of the original forest growth. On the coast of Georgia, in Florida, and in the coast plain of the eastern Gulf States, the loblolly pine is scattered among the Cuban and the longleaf pine; there its second growth meets a formidable competitor in the first named of these species. In the flat woods, deprived of drainage, the Cuban pine is always found to vastly outnumber the loblolly among the young forest growth. In the upper part of the great maritime pine belt the loblolly pine is frequently found among the mixed growth of magnolia, Spanish, red, post, and blackjack oaks, mockernut and pignut hickory, shortleaf pine,

LOBLOLLY PINE (PINUS TÆDA), TYPICAL TREES.



LOBLOLLY PINE (PINUS TÆDA L.).

a, aments of female flowers; *b*, immature cone, one season's growth; *c*, mature cone; *d*, open cone; *e*, *f*, cone scales, outer and inner side; *g*, seed and wing.

and southern spruce pine. Throughout this region the tree takes almost undisputed possession of the old fields.

In the interior, on the uplands of oaks and shortleaf pine, the loblolly is sure to gain the upper hand and to retain its hold among the young forest growth, giving way to its most aggressive competitor, the shortleaf pine, only when under the disadvantage of a greater exposure and a greater lack of moisture in the soil.

Enemies.—Principally confined to low, damp localities, not easily liable to invasion by the frequent conflagrations which scour the southern pine forests, the loblolly pine suffers less from destruction by fire than any other species. In virtue of the inherent facilities for its natural renewal resulting from its fecundity and from the rapidity of its development from the earliest stages of growth, any damages inflicted by that agency are more easily repaired. The same causes afford it also greater protection against incursions of live stock. As also observed in the shortleaf pine, the rapidly growing seedlings form, after a few years, thickets of such density as to be avoided by the larger quadrupeds, and by the time such thickets, in the course of natural thinning out have become more open, the trees have reached dimensions which place them beyond the danger of being tramped down or otherwise injured by live stock. The rapid spread and thrift of the second growth, unprotected and uncared for, observed everywhere within the range of the distribution of this pine, are witnesses to its greater immunity from such dangers.

Owing to the large amount of sapwood, the timber of the loblolly is more liable to the attacks of fungi and to the ravages of insects. The mycelium (spawn) of large polyporous fungi is found frequently infesting the woody tissue of the living tree, the hyphæ (filaments) of the spawn destroying the walls of the wood cells, causing the wood to assume a reddish color and rendering it brittle in the same way as is observed in the living longleaf-pine timber affected with the disease called "red heart." It seems that the destruction caused by this disease in the loblolly pine is from the start more rapid in consequence of the larger proportions of sapwood, and perhaps also on account of the broader bands of soft spring wood naturally accompanying wood of rapid growth.

In a piece of wood examined in north Alabama, the filaments of the spawn of one of these fungi crossing each other in every direction were found to form a dense film interposed between the spring and summer wood, causing its easy separation in the direction of the concentric rings, and, as the destruction of the wood proceeds, forming finally a compact layer of the nature of amadou, or tinder. In the longitudinal section the rays were found full of cavities, caused by the breaking down of the cell walls, and these cavities were filled with the white film of these filaments, which similarly affected the adjoining tracheids of the resinous summer wood.

The felled timber left on the ground is soon infested by a host of fungi of the genera *Agaricus*, *Tramites*, *Lentinus*, *Polyporus*, and others, the nearer identification of which has not been undertaken.

From the very limited observations that have been made it clearly appears that this pine suffers equally as much, if not more, than the other pines of Southern growth from insect enemies of various kinds. The larvæ of the same capricorn beetles (*Cerambicidæ*) burrow in the body of the timber. Those of the roundheaded borers (*Coleophora*) dig their channels in the sapwood, as is indicated by the occurrence of several species of jumping beetles (*Buprestidæ*) which are found clinging to the leaves and branches of this tree. The most fatal injury it sustains is caused by the bark borers (*Tomicidæ*), this pest particularly affecting the trees during the formation of the last cambium layer in the later summer months. Trees felled in August are immediately infested by multitudes of these destroyers. Favored by a high temperature and an abundance of nourishment, several generations of them succeed each other before the close of the season, the countless broods soon infesting every tree in the vicinity and carrying their work of destruction over the full expanse of the young forest growth. Under this affliction the forests often present, by their drooping rusty-colored foliage, a sad picture of disease and decay. Weevils (*Curculionidæa*) deposit their eggs in the youngest tender shoots; the larvæ which hatch from them eat their way into these shoots, causing their decay, and thus destroy the symmetry of the tree and impair the usefulness of the resulting timber. Other species of the same family puncture the older branches, lay their eggs in the exuded resin, their larvæ injuring the tree in a similar way. The larvæ of spittle insects injure the terminal buds, which are also found infested by the larvæ of pitch moths (*Retiniæ*), causing them to wither. The foliage seems to be less frequently

attacked by sawflies (*Lophyrus*) than the tender young leaves of the longleaf pine, as by the rapidity of their growth the young leaves sooner harden, and are therefore less relished by these depredators. The evidences of the work of the pine-leaf miners (caterpillar of *Gelechia*) have been frequently observed in Alabama, and everywhere are seen the deformities caused by gallflies and scale insects.

Natural reproduction.—If the shortleaf pine has been spoken of emphatically as the future timber tree of the light-rolling uplands of the interior, the loblolly pine might be fitly designated as the timber tree of greatest promise in a large part of the coast plain from the Middle Atlantic States to the limits of compact forest growth beyond the Mississippi River. The promptness with which it colonizes the old fields and other clearings, and the tenacity with which it retains from one generation to another the ground once taken possession of, clearly point to the important part this tree is to take when the ruthless stripping of timber lands practiced at present gives place to the management of the forests under a system of fostering care, tending to their future maintenance and to the disposal of their resources on the principle of true economy with an eye to the future welfare of the country. No timber tree will be found better adapted for forest planting in the southern part of the Atlantic forest division. It is only in the narrow belt of flat woods along the shores of Florida, Georgia, and the eastern Gulf region that it is likely to find its superior in the Cuban pine (*Pinus heterophylla*).

Besides the advantages of adaptability to varied soil and climate it excels in rapidity of growth during the earliest stages, and the copious production of seeds which, almost without fail, are plentifully distributed every year over the vicinity of the parent trees. As an evidence of the facility with which the reproduction of a compact forest by this pine is effected, it is only necessary to point out the spontaneous groves near the settlements, representing, as they do, every stage of development.

In the coast region the second growth, if not interfered with under proper soil conditions, yields in fifty to sixty years timber of dimensions rendering it fit to be sawn into lumber well adapted for various uses, as already mentioned.

Conclusion.—In this attempt at a sketch of the life history of this tree, the object was constantly kept in view of placing its value among the products of the Southern forests in the proper light. From the consideration of the structure of the wood and its physical properties, it clearly appears that although inferior to the wood of the longleaf and Cuban pines, the timber of this species fully equals that of shortleaf pine, and that the present practice of treating them as equivalent seems therefore justified.

As an abundant and cheap source of timber of inferior grades, and especially when the rapidity of its growth is considered, the loblolly pine is of no less economic importance than the other timber trees of the same section. At present held in low esteem in the great lumbering districts of the lower South, where the supplies of the superior timber of the longleaf pine still abound and receive the preference, the value of the timber of the loblolly pine is quickly recognized in other districts which, but a short while ago boasting of large resources, are now stripped of them. Its physiological peculiarities make it an important factor in the future forestry of this section. Its propagation is successful over a vast expanse in the southern section of the Atlantic forest region, and by its productive capacity, mode of development, and behavior toward competing species in the struggle for existence, the loblolly pine possesses great advantages for its natural and artificial renewal, adapting it particularly for the restoration of the forests on the lowlands of the maritime region.

Comparative Rate of Growth.

The species naturally develop somewhat differently, according to the soil conditions in which they occur. Without going into a detailed discussion, which may be found in the bulletin referred to, a comparison of the rate of growth of the four species, based on a large number of measurements, gave, for average trees and average conditions, the results shown in the accompanying diagrams (figs. 1 to 3), which permit the determination of the rate of growth at different periods of their life.

From these it appears that the Cuban pine is by far the most rapid grower, while the longleaf pine, which usually grows associated with the former, is the slowest, loblolly and shortleaf occupying a position between the two.

The longleaf shows for the first five to seven years hardly any development in height, and begins then to grow rapidly and evenly to the fiftieth or seventieth year, and even after that period, though the rate is somewhat diminished, progresses evenly and steadily, giving to the height curve a smooth and persistent character.

The diameter growth shows the same even and persistent progress from the start, and the volume growth also progresses evenly after the rapid height-growth rate is passed at seventy years.

The Cuban pine ceases in its maximum rate of height growth at thirty years, starts with its diameter growth at about the rate of the loblolly, but after the twenty-fifth year leaves the latter behind for the next twenty-five to thirty years, then proceeds at about the same rate, but persisting longer than the loblolly. At the age of fifty years the Cuban pine with 46 cubic feet has made nearly twice the amount of the loblolly and more than four times that of the longleaf;

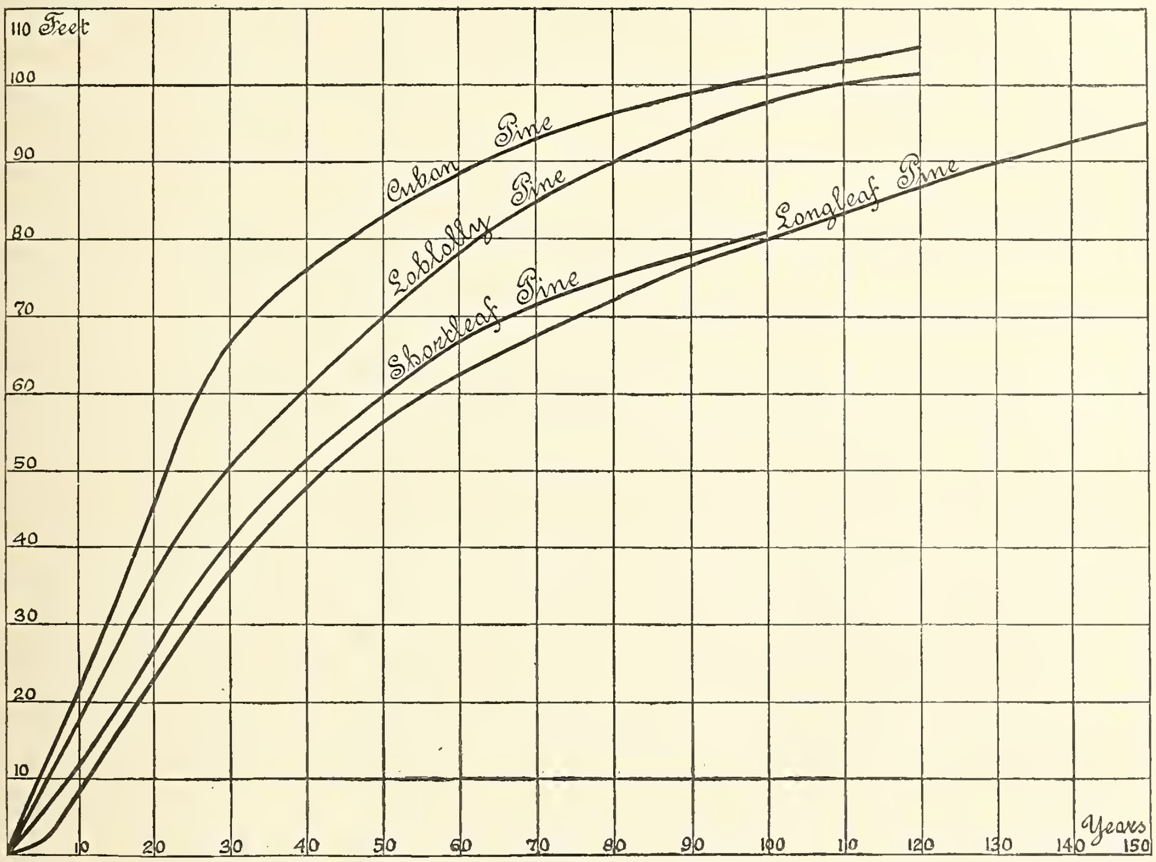


FIG. 1—Diagram showing comparative progress of height growth in average trees.

but at one hundred years the difference is reduced, being then 115, 90, and 55 cubic feet, respectively, for the three species.

Both loblolly and shortleaf pine reach their maximum growth sooner than the other two species. While these still show a persistently ascending line at one hundred and twenty to one hundred and forty years, the rate of growth in the loblolly shows a decline after the one-hundredth year, and the shortleaf has done its best by the eightieth year. These facts give indications as to the rotation under which these various species may be managed.

As stated before, the growth of trees, especially in the virgin forest, is quite variable even for the same species and same soil conditions. An average, therefore, like the one presented in the diagrams, however perfect, could apply only when large numbers are considered. Thus there are fast-growing trees of longleaf and slow growing of Cuban or loblolly pine. Yet the diagrams will fairly well represent the average growth, with the possible exception of the Cuban pine, for which the number of measurements was too small to furnish reliable data.

AMERICAN WOODS.

The great variety of trees already enumerated furnishes almost as great a variety of characteristic woods. There is, perhaps, no country in the world which can command such a wealth of woods for strictly useful purposes, although the Tropics may yield a larger variety of ornamental woods. The work of the Division of Forestry has concerned itself largely with the study of American woods, the crop of American forests. It is, therefore, appropriate to include in this report a brief résumé, giving a description of the various kinds of wood and their present application in the arts, reproduced from Bulletin 10.

In the countries of Europe the kinds of wood used in construction and manufacture are so few that there is but little difficulty in distinguishing them. In our own country the great variety of woods, and of useful woods at that, often makes the mere distinction of the kind or species of

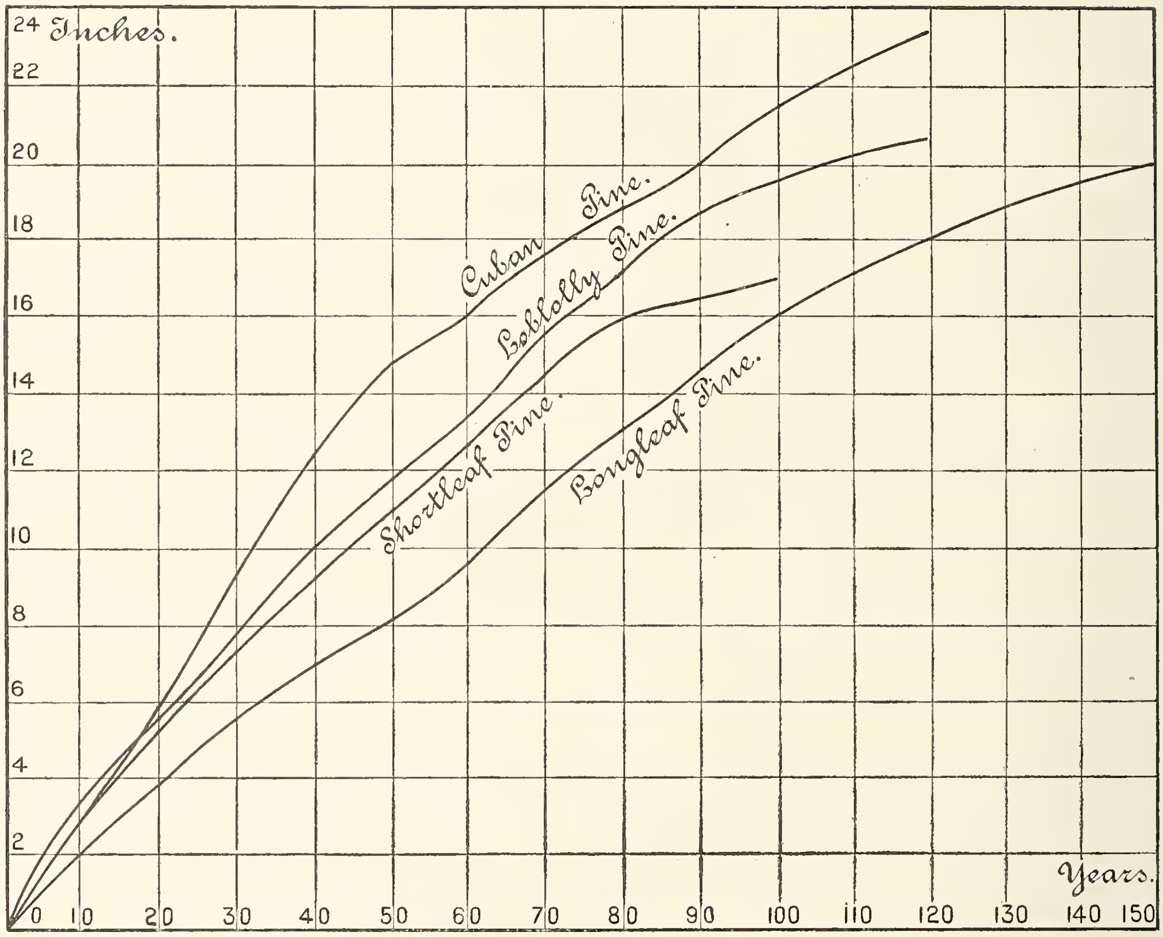


FIG. 2—Diagram showing comparative progress of diameter growth in average trees.

tree most difficult. Thus there are at least eight pines (of the thirty-five native ones) in the market, some of which so closely resemble each other in their minute structure that they can hardly be told apart; and yet they differ in quality and should be used separately, although they are often mixed or confounded in the trade. Of the thirty-six oaks, of which probably not less than six or eight are marketed, we can readily recognize by means of their minute anatomy at least two tribes—the white and the black oaks. The distinction of the species is, however, as yet uncertain. The same is true as to the eight kinds of hickory, the six kinds of ash, etc. Before we shall be able to distinguish the wood of these species unfailingly more study will be necessary. The key given in the present publication, therefore, is by necessity only provisional, requiring further elaboration. It unfortunately had to be based largely on external appearances, which are not always reliable. Sometimes, for general practical purposes, this mere appearance, with

some minor attributes, such as color, taste, etc., are together sufficient, especially when the locality is known from which the species came, and in the log pile the determination may by these means be rendered possible when a single detached piece will leave us doubtful as to the species. In the market the distinctions are often most uncertain, and a promiscuous application of names adds to the confusion. To be sure, there is not much virtue in knowing the correct name, except that it assists us in describing the exact kind of material we desire to obtain. Nor is there always much gained in being able to identify the species of wood, but that it predicates certain qualities which are usually found in the species.

In selecting material, then, for special purposes we first determine what species to use as having either one quality which is foremost in our requirements, or several qualities in combination, as shown by actual experience or by experiment.

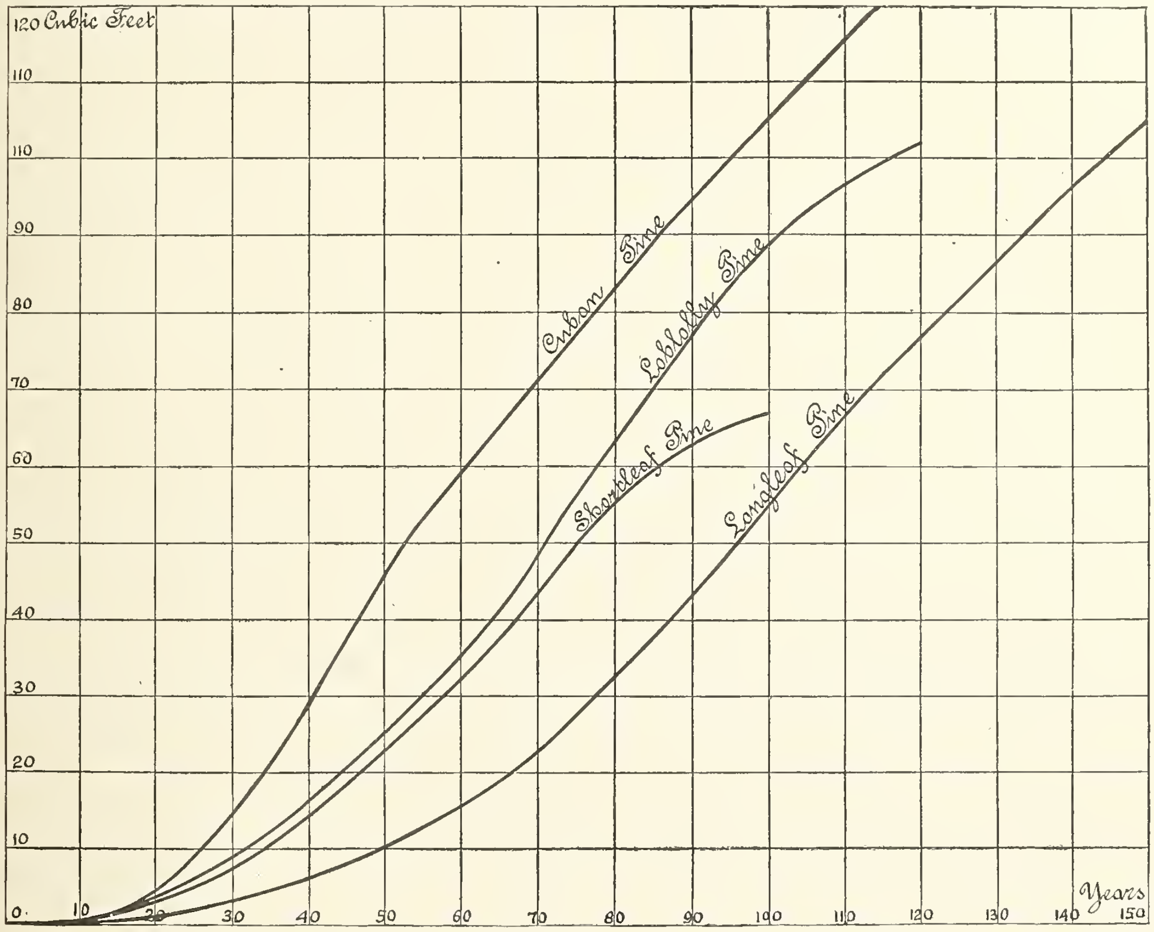


FIG. 3—Diagram showing comparative progress of volume growth in average trees.

The uses of the various woods depend on a variety of conditions. The carpenter and builder, using large quantities of material and bestowing a minimum amount of labor on the greater part of the same, uses those kinds which are abundant, and hence cheap, to be had in large dimensions, light to ship, soft to work and to nail, and fairly stiff and insect proof—a combination represented in the conifers. They need not be handsome, hard, tough, or very strong, and may shrink even after they are in place. When it comes to finishing-woods, more stress is laid on color and grain and that the wood shall shrink as little as possible.

The furniture maker, who bestows a maximum amount of work on his material, needs a wood that combines strength, and sometimes toughness, with beauty and hardness, that takes a good polish, keeps joint, and does not easily indent. It must not warp or shrink when once in place, but it need not be light or soft or insect proof or abundant in any one kind, and in large dimensions, nor yet particularly cheap.

Toughness, strength, and hardness combined are sought by the wagon maker. The carriage builder, cooper, and shingle maker look for straight-grained, easy splitting woods, and for a long fiber, the absence of disturbing resinous and coloring matter, knots, etc. Durability under exposure to the weather, resistance to indentation, and the holding of spikes are required for a good railroad tie; lasting qualities, elasticity, and proportionate dimensions of length and diameter for telegraph poles.

Sometimes in practice it is immaterial whether the stick be of white oak or red oak, and many wood yards make no distinction, in fact do not know any, but the experienced cooper will quickly distinguish, not by name, perhaps, but by quality, the more porous red or black oak from the less porous white species. On the other hand, the very same white oak—*Quercus alba*, usually a superior article—may furnish so poor material for a handle or a plow beam that a stick of red oak would be preferable. The inspection, then, must be made not only for the species but for the quality, with reference to the purpose for which the stick is to be used.

LIST OF THE MORE IMPORTANT WOODS OF THE UNITED STATES.

A. CONIFEROUS WOODS.

Woods of simple and uniform structure, generally light, soft but stiff; abundant in suitable dimensions and forming by far the greatest part of all the lumber used.

Cedar.—Light, soft, stiff, not strong, of fine texture; sap and heartwood distinct, the former lighter, the latter a dull grayish brown, or red. The wood seasons rapidly, shrinks and checks but little, and is very durable. Used like soft pine, but owing to its great durability preferred for shingles, etc. Small sizes used for posts, ties, etc.[1] Cedars usually occur scattered, but they form, in certain localities, forests of considerable extent.

a. White cedars.—Heartwood a light grayish brown.

1. White cedar (*Thuya occidentalis*) (Arborvitæ): Scattered along streams and lakes, frequently covering extensive swamps; rarely large enough for lumber, but commonly used for posts, ties, etc. Maine to Minnesota and northward.
2. Canoe cedar (*Thuya plicata*) (red cedar of the West): In Oregon and Washington a very large tree, covering extensive swamps; in the mountains much smaller, skirting the water courses; an important lumber tree. Washington to northern California and eastward to Montana.
3. White cedar (*Chamæcyparis thyoides*): Medium-sized tree, wood very light and soft. Along the coast from Maine to Mississippi.
4. White cedar (*Chamæcyparis lawsoniana*) (Port Orford cedar, Oregon cedar, Lawson's cypress, ginger pine): A very large tree, extensively cut for lumber; heavier and stronger than the preceding. Along the coast line of Oregon.
5. White cedar (*Libocedrus decurrens*) (incense cedar): A large tree, abundantly scattered among pine and fir; wood fine grained. Cascades and Sierra Nevada of Oregon and California.

b. Red cedars.—Heartwood red.

6. Red cedar (*Juniperus virginiana*) (Savin juniper): Similar to white cedar, but of somewhat finer texture. Used in cabinetwork in cooperage, for veneers, and especially for lead pencils, for which purpose alone several million feet are cut each year. A small to medium sized tree scattered through the forests, or, in the West, sparsely covering extensive areas (cedar brakes). The red cedar is the most widely distributed conifer of the United States, occurring from the Atlantic to the Pacific and from Florida to Minnesota, but attains a suitable size for lumber only in the Southern, and more especially the Gulf, States.
7. Redwood (*Sequoia sempervirens*): Wood in its quality and uses like white cedar; the narrow sapwood whitish; the heartwood light red, soon turning to brownish red when exposed. A very large tree, limited to the coast ranges of California, and forming considerable forests, which are rapidly being converted into lumber.

Cypress.

8. Cypress (*Taxodium distichum*) (bald cypress; black, white, and red cypress): Wood in appearance, quality, and uses similar to white cedar. "Black cypress" and "white cypress" are heavy and light forms of the same species. The cypress is a large deciduous tree, occupying much of the swamp and overflow land along the coast and rivers of the Southern States.

Fir.—This name is frequently applied to wood and to trees which are not fir; most commonly to spruce, but also, especially in English markets, to pine. It resembles spruce, but is easily distinguished from it, as well as from pine and larch, by the absence of resin ducts. Quality, uses, and habits similar to spruce.

9. Balsam fir (*Abies balsamea*): A medium-sized tree scattered throughout the northern pineries; cut, in lumber operations whenever of sufficient size, and sold with pine or spruce. Minnesota to Maine and northward.
10. White fir (*Abies grandis* and *Abies concolor*): Medium to very large sized trees, forming an important part of most of the Western mountain forests, and furnishing much of the lumber of the respective regions. The former occurs from Vancouver to central California and eastward to Montana; the latter from Oregon to Arizona and eastward to Colorado and New Mexico.

[1] Since almost all kinds of woods are used for fuel and charcoal, and in the construction of fences, sheds, barns, etc., the enumeration of these uses has been omitted in this list.

11. White fir (*Abies amabilis*): Good-sized tree, often forming extensive mountain forests. Cascade Mountains of Washington and Oregon.
12. Red fir (*Abies nobilis*) (not to be confounded with Douglas fir; see No. 37): Large to very large tree, forming, with *A. amabilis*, extensive forests on the slope of the mountains between 3,000 and 4,000 feet elevation. Cascade Mountains of Oregon.
13. Red fir (*Abies magnifica*): Very large tree, forming forests about the base of Mount Shasta. Sierra Nevada of California, from Mount Shasta southward.

Hemlock.—Light to medium weight, soft, stiff but brittle, commonly crossgrained, rough and splintery; sapwood and heartwood not well defined; the wood of a light, reddish-gray color, free from resin ducts, moderately durable, shrinks and warps considerably, wears rough, retains nails firmly. Used principally for dimension stuff and timbers. Hemlocks are medium to large sized trees, commonly scattered among broad-leaved trees and conifers, but often forming forests of almost pure growth.

14. Hemlock (*Tsuga canadensis*): Medium-sized tree, furnishes almost all the hemlock of the Eastern market. Maine to Wisconsin; also following the Alleghanies southward to Georgia and Alabama.
15. Hemlock (*Tsuga mertensiana*): Large-sized tree, wood claimed to be heavier and harder than the Eastern form and of superior quality. Washington to California and eastward to Montana.

Larch or tamarack.—Wood like the best of hard pine, both in appearance, quality, and uses, and owing to its great durability, somewhat preferred in shipbuilding, for telegraph poles, and railroad ties. In its structure it resembles spruce. The larches are deciduous trees, occasionally covering considerable areas, but usually scattered among other conifers.

16. Tamarack (*Larix laricina*) (Hackmatack): Medium-sized tree, often covering swamps, in which case it is smaller and of poor quality. Maine to Minnesota and southward to Pennsylvania.
17. Tamarack (*L. occidentalis*): Large-sized trees, scattered, locally abundant. Washington and Oregon to Montana.

Pine.—Very variable, very light and soft in "soft" pine, such as white pine; of medium weight to heavy and quite hard in "hard" pine, of which longleaf or Georgia pine is the extreme form. Usually it is stiff, quite strong, of even texture, and more or less resinous. The sapwood is yellowish white; the heartwood orange-brown. Pine shrinks moderately, seasons rapidly, and without much injury; it works easily; is never too hard to nail (unlike oak or hickory); it is mostly quite durable, and if well seasoned is not subject to the attacks of boring insects. The heavier the wood, the darker, stronger, and harder it is, and the more it shrinks and checks. Pine is used more extensively than any other kind of wood. It is the principal wood in common carpentry, as well as in all heavy construction, bridges, trestles, etc. It is also used in almost every other wood industry, for spars, masts, planks, and timbers in shipbuilding, in car and wagon construction, in cooperage, for crates and boxes, in furniture work, for toys and patterns, railway ties, water pipes, excelsior, etc. Pines are usually large trees with few branches, the straight, cylindrical, useful stem forming by far the greatest part of the tree; they occur gregariously, forming vast forests, a fact which greatly facilitates their exploitation. Of the many special terms applied to pine as lumber, denoting sometimes differences in quality, the following deserve attention:

"White pine," "pumpkin pine," "soft pine," in the Eastern markets, refer to the wood of the white pine (*Pinus strobus*), and on the Pacific coast to that of the sugar pine (*Pinus lambertiana*).

"Yellow pine" is applied in the trade to all the Southern lumber pines; in the Northeast it is also applied to the pitch pine (*P. rigida*); in the West it refers mostly to bull pine (*P. ponderosa*).

"Yellow longleaf pine," "Georgia pine," chiefly used in advertisement, refers to longleaf pine (*P. palustris*).

"Hard pine" is a common term in carpentry, and applies to everything except white pine.

"Pitch pine" includes all Southern pines and also the true pitch pine (*P. rigida*), but is mostly applied, especially in foreign markets, to the wood of the longleaf pine (*P. palustris*).

For the great variety of confusing local names applied to the Southern pines in their homes, part of which have been adopted in the markets of the Atlantic seaboard, see report of Chief of Division of Forestry for 1891, page 212, etc., and also the list below:

a. Soft pines.

18. White pine (*Pinus strobus*): Large to very large size tree; for the last fifty years the most important timber tree of the Union, furnishing the best quality of soft pine. Minnesota, Wisconsin, Michigan, New England, along the Alleghanies to Georgia.
19. Sugar pine (*Pinus lambertiana*): A very large tree, together with *Abies concolor*, forming extensive forests; important lumber tree. Oregon and California.
20. White pine (*Pinus monticola*): A large tree, at home in Montana, Idaho, and the Pacific States; most common and locally used in northern Idaho.
21. White pine (*Pinus flexilis*): A small tree, forming mountain forests of considerable extent and locally used; eastern Rocky Mountain slopes; Montana to New Mexico.

b. Hard pines.

22. Longleaf pine (*Pinus palustris*) (Georgia pine, yellow pine, long-straw pine, etc.): Large tree; forms extensive forests, and furnishes the hardest and strongest pine lumber in the market. Coast region from North Carolina to Texas.
23. Bull pine (*Pinus ponderosa*) (yellow pine): Medium to very large sized tree, forming extensive forests in Pacific and Rocky Mountain regions; furnishes most of the hard pine of the West; sapwood wide; wood very variable.

24. Loblolly pine (*Pinus tæda*) (slash pine, old-field pine, rosemary pine, sap pine, short-straw pine, etc.): Large-sized tree; forms extensive forests; wider-ringed, coarser, lighter, softer, with more sapwood than the longleaf pine, but the two often confounded. This is the common lumber pine from Virginia to South Carolina, and is found extensively in Arkansas and Texas. Southern States; Virginia to Texas and Arkansas.
25. Norway pine (*Pinus resinosa*): Large-sized tree, never forming forests, usually scattered or in small groves, together with white pine; largely sapwood and hence not durable. Minnesota to Michigan; also in New England to Pennsylvania.
26. Shortleaf pine (*Pinus echinata*) (slash pine, Carolina pine, yellow pine, old field pine, etc.): Resembles loblolly pine; often approaches in its wood the Norway pine. The common lumber pine of Missouri and Arkansas. North Carolina to Texas and Missouri.
27. Cuban pine (*Pinus heterophylla*) (slash pine, swamp pine, bastard pine, meadow pine): Resembles longleaf pine, but commonly has wider sapwood and coarser grain; does not enter the markets to any great extent. Along the coast from South Carolina to Louisiana.
28. Bull pine (*Pinus jeffreyi*) (black pine): Large-sized tree, wood resembling bull pine (*P. ponderosa*); used locally in California, replacing *P. ponderosa* at high altitudes.

The following are small to medium sized pines, not commonly offered as lumber in the market; used locally for timber, ties, etc.:

29. Black pine (*Pinus murrayana*) (lodge-pole pine, tamarack): Rock Mountains and Pacific regions.
30. Pitch pine (*Pinis rigida*): Along the coast from New York to Georgia and along the mountains to Kentucky.
31. Jersey pine (*Pinus virginiana*) (scrub pine): As before.
32. Gray pine (*Pinus divaricata*) (scrub pine): Maine, Vermont, and Michigan to Minnesota.

Redwood. (See *Cedar.*)

Spruce.—Resembles soft pine, is light, very soft, stiff, moderately strong, less resinous than pine; has no distinct heartwood, and is of whitish color. Used like soft pine, but also employed as resonance wood and preferred for paper pulp. Spruces, like pines, form extensive forests; they are more frugal, thrive on thinner soils, and bear more shade, but usually require a more humid climate. "Black" and "white spruce," as applied by lumbermen, usually refer to narrow and wide ringed forms of the black spruce (*Picea nigra.*)

33. Black spruce (*Picea mariana*): Medium-sized tree, forms extensive forests in northeastern United States and in British America; occurs scattered or in groves, especially in lowlands throughout the Northern pineries. Important lumber tree in Eastern United States. Maine to Minnesota, British America, and on the Alleghanies to North Carolina.
34. White spruce (*Picea alba*): Generally associated with the preceding; most abundant along streams and lakes, grows largest in Montana, and forms the most important tree of the subarctic forest of British America. northern United States, from Maine to Minnesota, also from Montana to Pacific, British America.
35. White spruce (*Picea engelmanni*): Medium to large sized tree, forming extensive forests at elevations from 5,000 to 10,000 feet above sea level; resembles the preceding, but occupies a different station. A very important timber tree in the central and southern parts of the Rocky Mountains. Rocky Mountains from Mexico to Montana.
36. Tide-land spruce (*Picea sitchensis*): A large-sized tree, forming an extensive coast-belt forest. Along the seacoast from Alaska to Central California.

Bastard Spruce.—Spruce, or fir in name, but resembling hard pine or larch in the appearance, quality, and uses of its wood.

37. Douglas spruce (*Pseudotsuga taxifolia*) (yellow fir, red fir, Oregon pine): One of the most important trees of the Western United States; grows very large in the Pacific States, to fair size in all parts of the mountains, in Colorado up to about 10,000 feet above sea level; forms extensive forests, often of pure growth. Wood very variable, usually coarse grained and heavy, with very pronounced summer wood, hard and strong ("red" fir), but often fine grained and light ("yellow" fir). It replaces hard pine and is especially suited to heavy construction. From the plains to the Pacific Ocean; from Mexico to British America.

Tamarack. (See *Larch.*)

Yew.—Wood heavy, hard, extremely stiff, and strong, of fine texture, with a pale yellow sapwood, and an orange-red heart; seasons well and is quite durable. Yew is extensively used for archery, bows, turner's ware, etc. The yews form no forests, but occur scattered with other conifers.

38. Yew (*Taxus brevifolia*): A small to medium sized tree of the Pacific region.

B. BROAD-LEAVED WOODS (Hardwoods).

Woods of complex and very variable structure, and therefore differing widely in quality, behavior, and consequently in applicability to the arts.

Ash.—Wood heavy, hard, strong, stiff, quite tough, not durable in contact with soil, straight-grained, rough on the split surface, and coarse in texture. The wood shrinks moderately, seasons with little injury, stands well, and takes a good polish. In carpentry ash is used for finishing lumber, stairways, panels, etc. It is used in shipbuilding, in the construction of cars, wagons, carriages, etc., in the manufacture of farm implements, machinery, and especially of furniture of all kinds, and also for harness work; for barrels, baskets, oars, tool handles, hoops, clothespins, and toys. The trees of the several species of ash are rapid growers, of small to medium height, with stout trunks; they form no forests, but occur scattered in almost all our broad-leaved forests.

39. White ash (*Fraxinus americana*): Medium, sometimes large-sized tree. Basin of the Ohio, but found from Maine to Minnesota and Texas.
40. Red ash (*Fraxinus pennsylvanica*): Small-sized tree. North Atlantic States, but extends to the Mississippi.

41. Black ash (*Fraxinus nigra*) (hoop ash, ground ash): Medium-sized tree, very common. Maine to Minnesota and southward to Virginia and Arkansas.

42. Blue ash (*Fraxinus quadrangulata*): Small to medium sized. Indiana and Illinois; occurs from Michigan to Minnesota and southward to Alabama.

43. Green ash (*Fraxinus viridis*): Small sized tree. New York to the Rocky Mountains and southward to Florida and Arizona.

44. Oregon ash (*Fraxinus oregana*): Medium-sized tree. Western Washington to California.

Aspen. (See *Poplar.*)

Basswood.

45. Basswood (*Tilia americana*) (lime tree, American linden, lin, bee tree): Wood light, soft, stiff but not strong, of fine texture, and white to light brown color. The wood shrinks considerably in drying, works and stands well; it is used in carpentry, in the manufacture of furniture and wooden ware, both turned and carved, in cooperage, for toys, also for paneling of car and carriage bodies. Medium to large sized tree, common in all Northern broad-leaved forests; found throughout the Eastern United States.

46. White basswood (*Tilia heterophylla*): A small-sized tree most abundant in the Allegheny region.

Beech.

47. Beech (*Fagus latifolia*): Wood heavy, hard, stiff, strong, of rather coarse texture, white to light brown, not durable in the ground, and subject to the inroads of boring insects; it shrinks and checks considerably in drying, works and stands well and takes a good polish. Used for furniture, in turnery, for handles, lasts, etc. Abroad it is very extensively employed by the carpenter, millwright, and wagon maker, in turnery as well as wood carving. The beech is a medium-sized tree, common, sometimes forming forest; most abundant in the Ohio and Mississippi basin, but found from Maine to Wisconsin and southward to Florida.

Birch.—Wood heavy, hard, strong, of fine texture; sapwood whitish, heartwood in shades of brown with red and yellow; very handsome, with satiny luster, equaling cherry. The wood shrinks considerably in drying, works and stands well and takes a good polish, but is not durable if exposed. Birch is used for finishing lumber in building, in the manufacture of furniture, in wood turnery for spools, boxes, wooden shoes, etc., for shoe lasts and pegs, for wagon hubs, ox yokes, etc., also in wood carving. The birches are medium-sized trees, form extensive forests northward, and occur scattered in all broad-leaved forests of the Eastern United States.

48. Cherry birch (*Betula lenta*) (black birch, sweet birch, mahogany birch): Small to medium-sized tree; very common. Maine to Michigan and to Tennessee.

49. Yellow birch (*Betula lutea*) (gray birch): Medium-sized tree; common. Maine to Minnesota and southward to Tennessee.

50. Red birch (*Betula nigra*) (river birch): Small to medium sized tree; very common; lighter and less valuable than the preceding. New England to Texas and Missouri.

51. Canoe birch (*Betula papyrifera*) (white birch, paper birch): Generally a small tree; common, forming forests; wood of good quality but lighter. All along the northern boundary of United States and northward, from the Atlantic to the Pacific.

Black walnut. (See *Walnut.*)

Blue beech.

52. Blue beech (*Carpinus caroliniana*) (hornbeam, water beech, ironwood): Wood very heavy, hard, strong, very stiff, of rather fine texture and white color; not durable in the ground; shrinks and checks greatly, but works and stands well. Used chiefly in turnery for tool handles, etc. Abroad, much used by mill and wheel wrights. A small tree, largest in the Southwest, but found in nearly all parts of the Eastern United States.

Bois d'arc. (See *Osage orange.*)

Buckeye—horse chestnut.—Wood light, soft, not strong, often quite tough, of fine and uniform texture and creamy white color. It shrinks considerably, but works and stands well. Used for wooden ware, artificial limbs, paper pulp, and locally also for building lumber. Small-sized trees, scattered.

53. Ohio buckeye ((*Æsculus glabra*) (fetid buckeye): Alleghenies, Pennsylvania to Indian Territory

54. Sweet buckeye (*Æsculus octandra*): Alleghenies, Pennsylvania to Texas.

Butternut.

55. Butternut (*Juglans cinerea*) (white walnut): Wood very similar to black walnut, but light, quite soft, not strong and of light brown color. Used chiefly for finishing lumber, cabinetwork, and cooperage. Medium-sized tree, largest and most common in the Ohio basin; Maine to Minnesota and southward to Georgia and Alabama.

Catalpa.

56. Catalpa (*Catalpa speciosa*): Wood light, soft, not strong, brittle, durable, of coarse texture and brown color; used for ties and posts, but well suited for a great variety of uses. Medium-sized tree; lower basin of the Ohio River, locally common. Extensively planted, and therefore promising to become of some importance.

Cherry.

57. Cherry (*Prunus serotina*): Wood heavy, hard, strong, of fine texture; sapwood yellowish white, heartwood reddish to brown. The wood shrinks considerably in drying, works and stands well, takes a good polish, and is much esteemed for its beauty. Cherry is chiefly used as a decorative finishing lumber for buildings, cars, and boats, also for furniture and in turnery. It is becoming too costly for many purposes for which it is naturally well suited. The lumber-furnishing cherry of this country, the wild black cherry (*Prunus serotina*), is a small to medium sized tree, scattered through many of the broad-leaved woods of the western slope of the Alleghenies, but found from Michigan to Florida and west to Texas. Other species of this genus, as well as the hawthorns (*Cratægus*) and wild apple (*Pyrus*), are not commonly offered in the market. Their wood is of the same character as cherry, often even finer, but in small dimensions.

Chestnut.

58. Chestnut (*Castanea dentata*): Wood light, moderately soft, stiff, not strong, of coarse texture; the sapwood light, the heartwood darker brown. It shrinks and checks considerably in drying, works easily, stands well, and is very durable. Used in cabinetwork, cooperage, for railway ties, telegraph poles, and locally in heavy construction. Medium-sized tree, very common in the Alleghenies, occurs from Maine to Michigan and southward to Alabama.

59. Chinquapin (*Castanea pumila*): A small-sized tree, with wood slightly heavier but otherwise similar to the preceding; most common in Arkansas, but with nearly the same range as the chestnut.

60. Chinquapin (*Castanopsis chrysophylla*): A medium-sized tree of the western ranges of California and Oregon.

Coffee tree.

61. Coffee tree (*Gymnocladus canadensis*) (coffee nut): Wood heavy, hard, strong, very stiff, of coarse texture, durable; the sapwood yellow, the heartwood reddish brown; shrinks and checks considerably in drying; works and stands well and takes a good polish. It is used to a limited extent in cabinetwork. A medium to large sized tree; not common. Pennsylvania to Minnesota and Arkansas.

Cottonwood. (See *Poplar.*)

Cucumber tree. (See *Tulip.*)

Elm.—Wood heavy, hard, strong, very tough; moderately durable in contact with the soil; commonly crossgrained, difficult to split and shape, warps and checks considerably in drying, but stands well if properly handled. The broad sapwood whitish, heart brown, both with shades of gray and red; on split surface rough; texture coarse to fine; capable of high polish. Elm is used in the construction of cars, wagons, etc., in boat and ship building, for agricultural implements and machinery; in rough cooperage, saddlery and harness work, but particularly in the manufacture of all kinds of furniture, where the beautiful figures, especially those of the tangential or bastard sections, are just beginning to be duly appreciated. The elms are medium to large sized trees, of fairly rapid growth, with stout trunk, form no forests of pure growth, but are found scattered in all the broad-leaved woods of our country, sometimes forming a considerable portion of the arborescent growth.

62. White elm (*Ulmus americana*) (American elm, water elm): Medium to large sized tree, common. Maine to Minnesota, southward to Florida and Texas.

63. Rock elm (*Ulmus racemosa*) (cork elm, hickory elm, white elm, cliff elm): Medium to large sized tree. Michigan, Ohio, from Vermont to Iowa, southward to Kentucky.

64. Red elm (*Ulmus pubescens*) (slippery elm, moose elm): Small-sized tree, found chiefly along water courses. New York to Minnesota, and southward to Florida and Texas.

65. Cedar elm (*Ulmus crassifolia*): Small-sized tree, quite common. Arkansas and Texas.

66. Winged elm (*Ulmus alata*) (Wahoo): Small-sized tree, locally quite common. Arkansas, Missouri, and eastern Virginia.

Gum.—This general term refers to two kinds of wood usually distinguished as sweet or red gum, and sour, black, or tupelo gum, the former being a relative of the witch-hazel, the latter belonging to the dogwood family.

67. Tupelo (*Nyssa sylvatica*) (sour gum, black gum): Maine to Michigan, and southward to Florida and Texas. Wood heavy, hard, strong, tough, of fine texture, frequently crossgrained, of yellowish or grayish white color, hard to split and work, troublesome in seasoning, warps and checks considerably, and is not durable if exposed; used for wagon hubs, wooden ware, handles, wooden shoes, etc. Medium to large sized trees, with straight, clear trunks; locally quite abundant, but never forming forests of pure growth.

68. Tupelo gum (*Nyssa aquatica*) (cotton gum): Lower Mississippi basin, northward to Illinois and eastward to Virginia, otherwise like preceding species.

69. Sweet gum (*Liquidambar styraciflua*) (red gum, liquidambar, bilsted): Wood rather heavy, rather soft, quite stiff and strong, tough, commonly crossgrained, of fine texture; the broad sapwood whitish, the heartwood reddish brown; the wood shrinks and warps considerably, but does not check badly, stands well when fully seasoned, and takes good polish. Sweet gum is used in carpentry, in the manufacture of furniture, for cut veneer, for wooden plates, plaques, baskets, etc., also for wagon hubs, hat blocks, etc. A large-sized tree, very abundant, often the principal tree in the swampy parts of the bottoms of the Lower Mississippi Valley; occurs from New York to Texas and from Indiana to Florida.

Hackberry.

70. Hackberry (*Celtis occidentalis*) (sugar berry): The handsome wood, heavy, hard, strong, quite tough, of moderately fine texture, and greenish or yellowish white color; shrinks moderately, works well, and takes a good polish. So far but little used in the manufacture of furniture. Medium to large sized tree, locally quite common, largest in the Lower Mississippi Valley; occurs in nearly all parts of the Eastern United States.

Hickory.—Wood very heavy, hard, and strong, proverbially tough, of rather coarse texture, smooth and of straight grain. The broad sapwood white, the heart reddish nut brown. It dries slowly, shrinks and checks considerably; is not durable in the ground, or if exposed, and, especially the sapwood, is always subject to the inroads of boring insects. Hickory excels as carriage and wagon stock, but is also extensively used in the manufacture of implements and machinery, for tool handles, timber pins, for harness work, and cooperage. The hickories are tall trees with slender stems, never form forests, occasionally small groves, but usually occur scattered among other broad-leaved trees in suitable localities. The following species all contribute more or less to the hickory of the markets:

71. Shagbark hickory (*Hicoria ovata* and *H. laciniosa*). Shellbark hickory: Medium to large sized trees, quite common; the favorite among hickories; best developed in the Ohio and Mississippi basins; from Lake Ontario to Texas, Minnesota to Florida. Shellbark more local.

72. Mockernut hickory (*Hicoria alba*) (black hickory, bull and black nut, big bud, and white-heart hickory): A medium to large sized tree, with the same range as the foregoing; common, especially in the South.
73. Pignut hickory (*Hicoria glabra*) (brown hickory, black hickory, switch-bud hickory): Medium to large sized tree, abundant; all eastern United States.
74. Bitternut hickory (*Hicoria minima*) (swamp hickory): A medium-sized tree, favoring wet localities, with the same range as the preceding.
75. Pecan (*Hicoria pecan*) (Illinois nut): A large tree, very common in the fertile bottoms of the Western streams; Indiana to Nebraska and southward to Louisiana and Texas.

Holly.

76. Holly (*Ilex opaca*): Wood of medium weight, hard, strong, tough, of fine texture and white color; works and stands well; used for cabinetwork and turnery. A small tree, most abundant in the Lower Mississippi Valley and Gulf States, but occurring eastward to Massachusetts and northward to Indiana.

Horse-chestnut. (See *Buckeye.*)

Ironwood. (See *Blue beech.*)

Locust.—This name applies to both of the following:

77. Black locust (*Robinia pseudacacia*) (black locust, yellow locust): Wood very heavy, hard, strong, and tough, of coarse texture, very durable in contact with the soil, shrinks considerably and suffers in seasoning; the very narrow sapwood yellowish, the heartwood brown, with shades of red and green. Used for wagon hubs, tree nails or pins, but especially for ties, posts, etc. Abroad it is much used for furniture and farm implements and also in turnery. Small to medium sized tree, at home in the Alleghenies; extensively planted, especially in the West.
78. Honey locust (*Gleditsia triacanthos*) (black locust, sweet locust, three-thorned acacia): Wood heavy, hard, strong, tough, of coarse texture, susceptible of a good polish, the narrow sapwood yellow, the heartwood brownish red. So far, but little appreciated except for fencing and fuel; used to some extent for wagon hubs and in rough construction. A medium-sized tree, found from Pennsylvania to Nebraska, and southward to Florida and Texas; locally quite abundant.

Magnolia. (See *Tulip.*)

Maple.—Wood heavy, hard, strong, stiff, and tough, of fine texture, frequently wavy-grained, this giving rise to "curly" and "blister" figures; not durable in the ground or otherwise exposed. Maple is creamy white, with shades of light brown in the heart; shrinks moderately, seasons, works and stands well, wears smoothly, and takes a fine polish. The wood is used for ceiling, flooring, paneling, stairway, and other finishing lumber in house, ship, and car construction; it is used for the keels of boats and ships, in the manufacture of implements and machinery, but especially for furniture, where entire chamber sets of maple rival those of oak. Maple is also used for shoe lasts and other form blocks, for shoe pegs, for piano actions, school apparatus, for wood type in show-bill printing, tool handles, in wood carving, turnery, and scroll work. The maples are medium-sized trees, of fairly rapid growth; sometimes form forests and frequently constitute a large proportion of the arborescent growth.

79. Sugar maple (*Acer saccharum*) (hard maple, rock maple): Medium to large sized tree, very common, forms considerable forests. Maine to Minnesota, abundant, with birch, in parts of the pineries; southward to northern Florida; most abundant in the region of the Great Lakes.
80. Red maple (*Acer rubrum*) (swamp or water maple): Medium-sized tree. Like the preceding, but scattered along water courses and other moist localities.
81. Silver maple (*Acer saccharinum*) (soft maple, silver maple): Medium-sized, common; wood lighter, softer, inferior to hard maple, and usually offered in small quantities and held separate in the market. Valley of the Ohio, but occurs from Maine to Dakota and southward to Florida.
82. Broad-leafed maple (*Acer macrophyllum*): Medium-sized tree, forms considerable forests, and, like the preceding, has a lighter, softer, and less valuable wood. Pacific Coast.

Mulberry.

83. Red mulberry (*Morus rubra*): Wood moderately heavy, hard, strong, rather tough, of coarse texture, durable; sapwood whitish, heart yellow to orange brown; shrinks and checks considerably in drying; works and stands well. Used in cooperage and locally in shipbuilding and in the manufacture of farm implements. A small-sized tree, common in the Ohio and Mississippi valleys, but widely distributed in the eastern United States.

Oak.—Wood very variable, usually very heavy and hard, very strong and tough, porous, and of coarse texture; the sapwood whitish, the heart "oak" brown to reddish brown. It shrinks and checks badly, giving trouble in seasoning, but stands well, is durable, and little subject to attacks of insects. Oak is used for many purposes—in shipbuilding, for heavy construction, in common carpentry, in furniture, car, and wagon work, cooperage, turning, and even in wood carving; also in the manufacture of all kinds of farm implements, wooden mill machinery, for piles and wharves, railway ties, etc. The oaks are medium to large sized trees, forming the predominant part of a large portion of our broad-leaved forests, so that these are generally "oak forests" though they always contain a considerable proportion of other kinds of trees. Three well-marked kinds, white, red, and live oak, are distinguished and kept separate in the market. Of the two principal kinds white oak is the stronger, tougher, less porous, and more durable. Red oak is usually of coarser texture, more porous, often brittle, less durable, and even more troublesome in seasoning than white oak. In carpentry and furniture work red oak brings about the same price at present as white oak. The red oaks everywhere accompany the white oaks, and, like the latter, are usually represented by several species in any given locality. Live oak, once

largely employed in shipbuilding, possesses all the good qualities (except that of size) of white oak, even to a greater degree. It is one of the heaviest, hardest, and most durable building timbers of this country; in structure it resembles the red oaks, but is much less porous.

84. White oak (*Quercus alba*): Medium to large sized tree, common in the Eastern States, Ohio and Mississippi valleys; occurs throughout eastern United States.
85. Bur oak (*Quercus macrocarpa*) (mossy-cup oak, over-cup oak): Large-sized tree, locally abundant, common. Bottoms west of Mississippi; range farther west than preceding.
86. Swamp white oak (*Quercus platanoides*): Large-sized tree, common. Most abundant in the Lake States, but with range as in white oak.
87. Chinquapin oak (*Quercus acuminata*) (chestnut oak): Medium-sized tree. Southern Alleghenies, eastward to Massachusetts.
88. Basket oak (*Quercus michauxii*) (cow oak): Large-sized tree, locally abundant; Lower Mississippi and eastward to Delaware.
89. Over-cup oak (*Quercus lyrata*) (swamp white oak, swamp post oak): Medium to large sized tree, rather restricted; ranges as in the preceding.
90. Post oak (*Quercus minor*) (iron oak): Medium to large sized tree. Arkansas to Texas, eastward to New England and northward to Michigan.
91. Chestnut oak (*Quercus prinus*): Medium to large sized tree. Throughout the Allegheny Mountains.
92. White oak (*Quercus garryana*): Medium to large sized tree. Washington to California.
93. White oak (*Quercus lobata*): Medium to large sized tree; largest oak on the Pacific coast; California.
94. Red oak (*Quercus rubra*) (black oak): Medium to large sized tree; common in all parts of its range. Maine to Minnesota, and southward to the Gulf.
95. Black oak (*Quercus velutina*) (yellow oak): Medium to large sized tree; very common in the Southern States, but occurring north as far as Minnesota, and eastward to Maine.
96. Spanish oak (*Quercus digitata*) (red oak): Medium-sized tree, common in the South Atlantic and Gulf region, but found from Texas to New York, and north to Missouri and Kentucky.
97. Scarlet oak (*Quercus coccinea*): Medium to large sized tree; best developed in the lower basin of the Ohio, but found from Maine to Missouri, and from Minnesota to Florida.
98. Pin oak (*Quercus palustris*) (swamp Spanish oak, water oak): Medium to large sized tree, common along borders of streams and swamps. Arkansas to Wisconsin, and eastward to the Alleghenies.
99. Willow oak (*Quercus phellos*) (peach oak): Small to medium sized tree. New York to Texas, and northward to Kentucky.
100. Water oak (*Quercus nigra*) (duck oak, possum oak, punk oak): Medium to large sized tree, of extremely rapid growth. Eastern Gulf States, eastward to Delaware and northward to Missouri and Kentucky.
101. Live oak (*Quercus virginiana*): Small-sized tree, scattered along the coast from Virginia to Texas.
102. Live oak (*Quercus chrysolepis*) (maul oak, Valparaiso oak): Medium-sized tree; California.

Osage orange.

103. Osage orange (*Toxylon pomiferum*)(Bois d'Arc): Wood very heavy, exceedingly hard, strong, not tough, of moderately coarse texture, and very durable; sapwood yellow, heart brown on the end, yellow on longitudinal faces, soon turning grayish brown if exposed; it shrinks considerably in drying, but once dry it stands unusually well. Formerly much used for wheel stock in the dry regions of Texas; otherwise employed for posts, railway ties, etc. Seems too little appreciated; it is well suited for turned ware and especially for wook carving. A small-sized tree of fairly rapid growth, scattered through the rich bottoms of Arkansas and Texas.

Persimmon.

104. Persimmon (*Diospyros virginiana*): Wood very heavy and hard, strong and tough; resembles hickory, but is of finer texture; the broad sapwood cream color, the heart black; used in turnery for shuttles, plane stocks, shoe lasts, etc. Small to medium sized tree, common and best developed in the lower Ohio Valley, but occurs from New York to Texas and Missouri.

Poplar and cottonwood (see also *Tulip wood*).—Wood light, very soft, not strong, of fine texture and whitish, grayish to yellowish color, usually with a satiny luster. The wook shrinks moderately (some crossgrained forms warp excessively), but checks little; is easily worked, but is not durable. Used as building and furniture lumber, in cooperage for sugar and flour barrels, for crates and boxes (especially cracker boxes), for wooden ware and paper pulp.

105. Cottonwood (*Populus deltoides*): Large-sized tree; forms considerable forests along many of the Western streams, and furnishes most of the cottonwood of the market. Mississippi Valley and west; New England to the Rocky Mountains.
106. Balsam (*Populus balsamifera*) (balm of Gilead): Medium to large-sized tree; common all along the northern boundary of the United States.
107. Black cottonwood (*Populus trichocarpa*): The largest deciduous tree of Washington; very common. Northern Rocky Mountains and Pacific region.
108. Cottonwood (*Populus fremontii* var. *wislizeni*): Medium to large-sized tree; common. Texas to California.
109. Poplar (*Populus grandidentata*): Medium-sized tree, chiefly used for pulp. Maine to Minnesota and southward along the Alleghenies.
110. Aspen (*Populus tremuloides*): Small to medium-sized tree, often forming extensive forests and covering burned areas. Maine to Washington and northward; south in the Western mountains to California and New Mexico.

Sour gum. (See *Gum.*)
Red gum. (See *Gum.*)
Sassafras.

111. Sassafras (*Sassafras sassafras*): Wood light, soft, not strong, brittle, of coarse texture, durable; sapwood yellow, heart orange brown. Used in cooperage, for skiffs, fencing, etc. Medium-sized tree, largest in the Lower Mississippi Valley. From New England to Texas and from Michigan to Florida.

Sweet gum. (See *Gum.*)
Sycamore.

112. Sycamore (*Platanus occidentalis*) (buttonwood, buttonball tree, water beech): Wood moderately heavy, quite hard, stiff, strong, tough, usually crossgrained, of coarse texture, and white to light brown color; the wood is hard to split and work, shrinks moderately, warps, and checks considerably, but stands well. It is used extensively for drawers, backs, bottoms, etc., in cabinetwork, for tobacco boxes, in cooperage, and also for finishing lumber where it has too long been underrated. A large tree of rapid growth, common and largest in the Ohio and Mississippi valleys, at home in nearly all parts of the Eastern United States. The California species—

113. *Platanus racemosa* resembles in its wood the Eastern form.

Tulip wood.

114. Tulip tree (*Liriodendron tulipifera*) (yellow poplar, whitewood): Wood quite variable in weight, usually light, soft, stiff but not strong, of fine texture, and yellowish color; the wood shrinks considerably, but seasons without much injury; works and stands remarkably well. Used for siding, for paneling, and finishing lumber in house, car, and ship building, for sideboards and panels of wagons and carriages; also in the manufacture of furniture, implements, and machinery, for pump logs, and almost every kind of common wooden ware, boxes, shelving, drawers, etc. An ideal wood for the carver and toy man. A large tree, does not form forests, but is quite common, especially in the Ohio basin; occurs from New England to Missouri and southward to Florida.

115. Cucumber tree (*Magnolia acuminata*): A medium-sized tree, most common in the southern Alleghenies, but distributed from New York to Arkansas, southward to Alabama and northward to Illinois. Resembling and probably confounded with tulip wood in the markets.

Tupelo. (See *Gum.*)
Walnut.

116. Black walnut (*Juglans nigra*): Wood heavy, hard, strong, of coarse texture; the narrow sapwood whitish, the heartwood chocolate brown. The wood shrinks moderately in drying, works and stands well, takes a good polish, is quite handsome, and has been for a long time the favorite cabinet wood in this country. Walnut, formerly used even for fencing, has become too costly for ordinary uses, and is to day employed largely as a veneer for inside finish and cabinetwork, also in turnery, for gunstocks, etc. Black walnut is a large tree with stout trunk, of rapid growth, and was formerly quite abundant throughout the Allegheny region, occurring from New England to Texas, and from Michigan to Florida.

White walnut. (See *Butternut.*)
White wood. (See *Tulip* and also *Basswood.*)
Yellow poplar. (See *Tulip.*)

COMPARATIVE STATEMENTS OF PROPERTIES OF AMERICAN WOODS.

Weight of kiln-dried wood of different species.

	Approximate.		
	Specific weight.	Weight of— 1 cubic foot.	Weight of— 1,000 feet of lumber.
		Pounds.	*Pounds.*
(*a*) Very heavy woods: Hickory, oak, persimmon, osage orange, black locust, hackberry, blue beech, best of elm, and ash	0.70–0.80	42–48	3,700
(*b*) Heavy woods: Ash, elm, cherry, birch, maple, beech, walnut, sour gum, coffee tree, honey locust, best of Southern pine, and tamarack	.60– .70	36–42	3,200
(*c*) Woods of medium weight: Southern pine, pitch pine, tamarack, Douglas spruce, western hemlock, sweet gum, soft maple, sycamore, sassafras, mulberry, light grades of birch and cherry	.50– .60	30–36	2,700
(*d*) Light woods: Norway and bull pine, red cedar, cypress, hemlock, the heavier spruce and fir, redwood, basswood, chestnut, butternut, tulip, catalpa, buckeye, heavier grades of poplar	.40– .50	24–30	2,200
(*e*) Very light woods: White pine, spruce, fir, white cedar, poplar	.30– .40	18–24	1,800

For scientific names see list above.

Since the proportion of sap and heart wood varies with size, age, species, and individual, the following figures must be regarded as mere approximations:

Pounds of water lost in drying 100 pounds of green wood in the kiln.

	Sapwood or outer part.	Heartwood or interior.
(1) Pines, cedars, spruces, and firs	45–65	16–25
(2) Cypress, extremely variable	50–65	18–60
(3) Poplar, cottonwood, basswood	50–65	40–60
(4) Oak, beech, ash, elm, maple, birch, hickory, chestnut, walnut, and sycamore	40–50	30–40

The lighter kinds have the most water in the sapwood, thus sycamore has more than hickory.

Since the shrinkage of our woods has never been carefully studied, and since wood, even from the same tree, varies within considerable limits, the figures given in the following table are to be regarded as mere approximations. The shrinkage along the radius and that along the tangent (parallel to the rings) are not stated separately in the following table, and the figures represent an average of the shrinkage in the two directions. Thus, if the shrinkage of soft pine is given at 3 inches per hundred, it means that the sum of radial and tangential shrinkage is about 6 inches, of which about 4 inches fall to the tangent and 2 inches to the radius, the ratio between these varying from 3 to 2, a ratio which practically prevails in most of our woods.

Since only an insignificant longitudinal shrinkage takes place (being commonly less than 0.1 inch per hundred), the change in volume during drying is about equal to the sum of the radial and tangential shrinkage, or twice the amount of linear shrinkage indicated in the table.

Thus, if the linear average shrinkage of soft pine is 3 inches per hundred, the shrinkage in volume is about 6 cubic inches for each 100 cubic inches of fresh wood.

Approximate shrinkage of a board, or set of boards, 100 inches wide, drying in the open air.

	Shrinkage.
	Inches.
(1) All light conifers (soft pine, spruce, cedar, cypress)	3
(2) Heavy conifers (hard pine, tamarack, yew), honey locust, box elder, wood of old oaks	4
(3) Ash, elm, walnut, poplar, maple, beech, sycamore, cherry, black locust	5
(4) Basswood, birch, chestnut, horse-chestnut, blue beech, young locust	6
(5) Hickory, young oak, especially red oak	Up to 10

Strength in compression of common American woods in well-seasoned selected pieces.

[Approximate weight per square inch of cross section requisite to crush a piece of wood endwise.]

	Pounds.
(1) Black locust, yellow and cherry birch, hard maple, best hickory, longleaf and Cuban pines, and tamarack	9,000+
(2) Common hickory, oak, birch, soft maple, walnut, good elm, best ash, shortleaf and loblolly pines, western hemlock, and Douglas fir	7,000+
(3) Ash, sycamore, beech, inferior oak, Pacific white cedar, canoe cedar, Lawson's cypress, common red cedar, cypress, Norway and superior spruces, and fir	6,000+
(4) Tulip, basswood, butternut, chestnut, good poplar, white and other common soft pines, hemlock, spruce, and fir	5,000+
(5) Soft poplar, white cedar, and some Western soft pines, and firs	4,000+

Strength in cross-breaking of well-seasoned, select pieces.

	Strength of the extreme fiber $f=\frac{3\ W\ l}{2\ bd^2}$ per square inch.	Approximate weight which breaks a stick— 1 by 1 inch and 12 inches long.	Approximate weight which breaks a stick— 2 by 2 inches and 10 feet long.
	Pounds.	*Pounds.*	*Pounds.*
(1) Robinia (locust), hard maple, hickory, oak, birch, best ash and elm, longleaf, shortleaf, and Cuban pines, tamarack	13,000	720	570
(2) Soft maple, cherry, ash, elm, walnut, inferior oak, and birch, best poplar, Norway, loblolly, and pitch pines, black and white spruce, hemlock, and good cedar	10,000	550	440
(3) Tulip, basswood, sycamore, butternut, poplars, white and other soft pines, firs, and cedars	6,500	350	280

From the following table of strength in tension and compression it will be seen that these two are not always proportional, the stiffer conifers excelling in the latter, the tougher hardwoods in the former:

Ratio of strength in tension and compression, showing the difference between rigid conifers and tough hard woods.

	Ratio: $R=\frac{\text{Tensile strength.}}{\text{comprehensive strength.}}$	A stick 1 square inch in cross section. Weight required to— Pull apart.	Crush endwise.
		Pounds.	*Pounds.*
Hickory	3.7	32,000	8,500
Elm	3.8	29,000	7,500
Larch	2.3	19,400	8,600
Longleaf pine	2.2	17,300	7,400

Table of stiffness (modulus of elasticity) of dry wood.—General averages.

Species.	Modulus of elasticity $E=\frac{W\,l^3}{4\,D\,bd^3}$ per square inch.	Approximate weight which deflects by 1 inch a piece— 1 by 1 inch and 12 inches long.	2 by 2 inches and 10 feet long.
	Pounds.	*Pounds.*	*Pounds.*
(1) Live oak, good tamarack, longleaf, Cuban, and shortleaf pine, good Douglas spruce, western hemlock, yellow and cherry birch, hard maple, beech, locust, and the best of oak and hickory	1,680,000	3,900	62
(2) Birch, common oak, hickory, white and black spruce, loblolly and red pine, cypress, best of ash, elm, and poplar and black walnut	1,400,000	3,200	51
(3) Maples, cherry, ash, elm, sycamore, sweet gum, butternut, poplar, basswood, white, sugar, and bull pine, cedars, scrub pine, hemlock, and fir	1,100,000	2,500	40
(4) Box elder, horse chestnut, a number of western soft pines, inferior grades of hard woods	1,100,000	[1] 2,500	40

[1] Less than.

In general wet or green wood shears about one-third more easily than dry wood; a surface parallel to the rings (tangent) shears more easily than one parallel to the medullary rays. The lighter conifers and hard woods offer less resistance than the heavier kinds, but the best of pine shears one-third to one-half more readily than oak or hickory, indicating that great shearing strength is characteristic of "tough" woods.

Resistance to shearing along the fiber.

	Per square inch.
	Pounds.
(1) Locust, oak, hickory, elm, maple, ash, birch	[1] 1,000
(2) Sycamore, longleaf, Cuban, and shortleaf pine, and tamarack	600
(3) Tulip, basswood, better class of poplar, Norway, loblolly, and white pine, spruce, red cedar	400
(4) Soft poplar, hemlock, white cedar, fir	[2] 400

[1] Over. [2] Less than.

NOTE.—Resistance to shearing, although a most important quality in wood, has not been satisfactorily studied. The values in the above table, taken from various authors, lack a reliable experimental basis and can be considered as only a little better than guesswork.

The following indicates the hardness of our common woods:

1. Very hard woods requiring over 3,200 pounds per square inch to produce an indentation of one-twentieth inch: Hickory, hard maple, osage orange, black locust, persimmon, and the best of oak, elm, and hackberry.

2. Hard woods requiring over 2,400 pounds per square inch to produce an indentation of one-twentieth inch: Oak, elm, ash, cherry, birch, black walnut, beech, blue beech, mulberry, soft maple, holly, sour gum, honey locust, coffee tree, and sycamore.

3. Middling hard woods, requiring over 1,600 pounds per square inch to produce an indentation of one-twentieth inch: The better qualities of Southern and Western hard pine, tamarack, and Douglas spruce, sweet gum, and the lighter qualities of birch.

4. Soft woods requiring less than 1,600 pounds per square inch to produce an indentation of one-twentieth inch: The greater mass of coniferous wood; pine, spruce, fir, hemlock, cedar, cypress, and redwood; poplar, tulip, basswood, butternut, chestnut, buckeye, and catalpa.

Range of durability in railroad ties.

	Years.		Years.
White oak and chestnut oak	8	Redwood	12
Chestnut	8	Cypress and red cedar	10
Black locust	10	Tamarack	7 to 8
Cherry, black walnut, locust	7	Longleaf pine	6
Elm	6 to 7	Hemlock	4 to 6
Red and black oaks	4 to 5	Spruce	5
Ash, beech, maple	4		

HOW TO DISTINGUISH THE DIFFERENT KINDS OF WOOD.

The carpenter or other artisan who handles different woods becomes familiar with those he employs frequently, and learns to distinguish them through this familiarity, without usually being able to state the points of distinction. If a wood comes before him with which he is not familiar, he has, of course, no means of determining what it is, and it is possible to select pieces even of those with which he is well acquainted, different in appearance from the general run, that will make him doubtful as to their identification. Furthermore, he may distinguish between hard and soft pines, between oak and ash, or between maple and birch, which are characteristically different; but when it comes to distinguishing between the several species of pine or oak or ash or birch, the absence of readily recognizable characters is such that but few practitioners can be relied upon to do it. Hence, in the market we find many species mixed and sold indiscriminately.

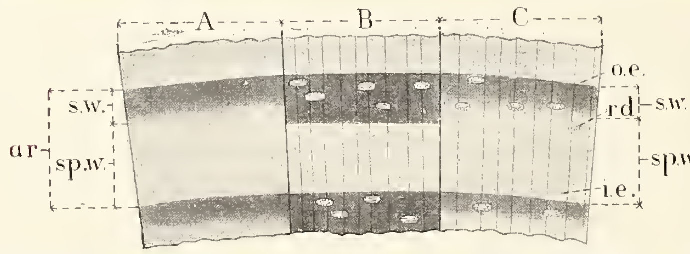


FIG. 4.—"Non-porous" woods. *A*, fir; *B*, "hard" pine; *C*, soft pine; *ar*, annual ring; *o. e.*, outer edge of ring; *i. e.*, inner edge of ring; *s. w.*, summer wood; *sp. w.*, spring wood; *rd*, resin ducts.

To identify the different woods it is necessary to have a knowledge of the definite, invariable differences in their structure, besides that of the often variable differences in their appearance. These structural differences may either be readily visible to the naked eye or with a magnifier, or they may require a microscopical examination. In some cases such an examination can not be dispensed with, if we would make absolutely sure. There are instances, as in the pines, where even our knowledge of the minute anatomical structure is not yet sufficient to make a sure identification.

In the following key an attempt has been made—the first, so far as we know, in English literature—to give a synoptical view of the distinctive features of the commoner woods of the United States which are found in the markets or are used in the arts. It will be observed that the distinction has been carried in most instances no further than to genera or classes of woods, since the distinction of species can hardly be accomplished without elaborate microscopic study, and also that, as far as possible, reliance has been placed only on such characteristics as can be distinguished with the naked eye or a simple magnifying glass, in order to make the key useful to the largest number. Recourse has also been taken for the same reason to the less reliable and more variable general external appearance, color, taste, smell, weight, etc.

The user of the key must, however, realize that external appearance, such, for example, as color, is not only very variable but also very difficult to describe, individual observers differing especially in seeing and describing shades of color. The same is true of statements of size, when relative, and not accurately measured, while weight and hardness can perhaps be more readily approximated. Whether any feature is distinctly or only indistinctly seen will also depend somewhat on individual eyesight, opinion, or practice. In some cases the resemblance of different species is so close that only one other expedient will make distinction possible, namely, a knowledge of the region from which the wood has come. We know, for instance, that no longleaf pine grows in Arkansas, and that no white pine can come from Alabama, and we can separate the white cedar, giant arbor vitæ of the West and the arbor vitæ of the Northeast only by the difference of the locality from which the specimen comes. With all these limitations properly

appreciated, the key will be found helpful toward greater familiarity with the woods which are more commonly met with.

The features which have been utilized in the key and with which—their names as well as their appearance—therefore, the reader must familiarize himself before attempting to use the key, are mostly described as they appear in cross section. They are:

(1) Sapwood and heartwood, the former being the wood from the outer and the latter from the inner part of the tree. In some cases they differ only in shade, and in others in kind of color, the heartwood exhibiting either a darker shade or a pronounced color. Since one can not always have the two together, or be certain whether he has sapwood or heartwood, reliance upon this feature is, to be sure, unsatisfactory, yet sometimes it is the only general characteristic that can be relied upon. If further assurance is desired, microscopic structure must be examined; in such cases reference has been made to the presence or absence of tracheids in pith rays and the structure of their walls, especially projecions and spirals.

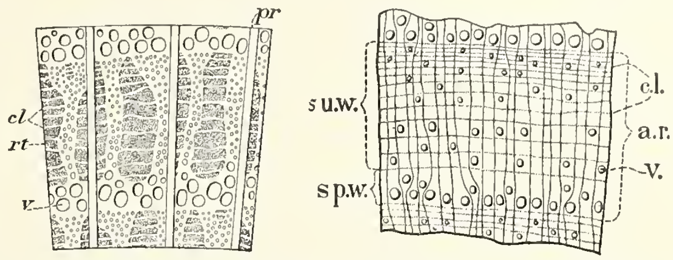


FIG. 5.—"Ring porous" woods—white oak and hickory. *a. r.*, annual ring; *su. w.*, summer wood; *sp. w.*, spring wood; *v*, vessels or pores; *c. l.*, "concentric" lines; *rt*, darker tracts of hard fibers forming the firm part of oak wood; *pr*, pith rays.

(2) Annual rings. They are more or less distinctly marked, and by means of such marking a classification of three great groups of wood is possible.

(3) Spring wood and summer wood, the former being the interior (first formed wood of the year), the latter the exterior (last formed) part of the ring. The proportion of each and the manner in which the one merges into the other are sometimes used, but more frequently the manner in which the pores appear distributed in either.

(4) Pores, which are vessels cut through, appearing as holes in cross section, in longitudinal section as channels, scratches, or indentations. They appear only in the broad-leaved, so called, hard woods; their relative size (large, medium, small, minute, and indistinct, when they cease to be visible individually by the naked eye) and manner of distribution in the ring being of much importance, and especially in the summer wood, where they appear singly, in groups, or short broken lines, in continuous concentric, often wavy, lines, or in radial branching lines.

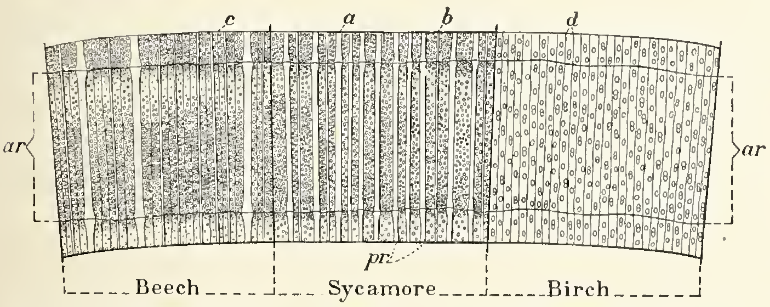


FIG. 6.—"Diffuse-porous" woods. *ar*, annual ring; *pr*, pith rays, which are "broad" at *a*, "fine" at *b*, "indistinct" at *d*.

(5) Resin ducts (see fig. 4), which appear very much like pores in cross section, namely, as holes or lighter or darker colored dots, but much more scattered. They occur only in coniferous woods, and their presence or absence, size, number, and distribution are an important distinction in these woods.

(6) Pith rays (see fig. 6), which in cross section appear as radial lines, and in radial section as interrupted bands of varying breadth, impart a peculiar luster to that section in some woods. They are most readily visible with the naked eye or with a magnifier in the broad-leaved woods. In coniferous woods they are usually so fine and closely packed that to the casual observer they do not appear. Their breadth and their greater or less distinctness are used as distinguishing marks, being styled fine, broad, distinct, very distinct, conspicuous, and indistinct when no longer visible by the naked (strong) eye.

(7) Concentric lines, appearing in the summer wood of certain species more or less distinct, resembling distantly the lines of pores but much finer and not consisting of pores. (See fig. 5).

Of microscopic features, the following only have been referred to:

(8) Tracheids.

(9) Pits, simple and bordered, especially the number of simple pits in the cells of the pith rays, which lead into each of the adjoining tracheids.

For standards of weight, consult table on page 95; for standards of hardness, statement on page 97.

Unless otherwise stated the color refers always to the fresh cross section of a piece of dry wood; sometimes distinct kinds of color, sometimes only shades, and often only general color effects appear.

HOW TO USE THE KEY.

Nobody need expect to be able to use successfully any key for the distinction of woods or of any other class of natural objects without some practice. This is especially true with regard to woods, which are apt to vary much, and when the key is based on such meager general data as the present. The best course to adopt is to supply one's self with a small sample collection of woods accurately named. Small, polished tablets are of little use for this purpose. The pieces should be large enough, if possible, to include pith and bark, and of sufficient width to permit ready inspection of the cross section. By examining these with the aid of the key, beginning with the better-known woods, one will soon learn to see the features described and to form an idea of the relative standards which the maker of the key had in mind. To aid in this, the accompanying illustrations will be of advantage. When the reader becomes familiar with the key, the work of identifying any given piece will be comparatively easy. The material to be examined must, of course, be suitably prepared. It should be moistened; all cuts should be made with a very sharp knife or razor and be clean and smooth, for a bruised surface reveals but little structure. The most useful cut may be made along one of the edges. Instructive, thin, small sections may be made with a sharp penknife or razor, and when placed on a piece of thin glass, moistened and covered with another piece of glass, they may be examined by holding them toward the light.

Finding, on examination with the magnifier, that it contains pores, we know it is not coniferous or nonporous. Finding no pores collected in the spring-wood portion of the annual ring, but all scattered (diffused) through the ring, we turn at once to the class of "Diffuse-porous woods." We now note the size and manner in which the pores are distributed through the ring. Finding them very small and neither conspicuously grouped, nor larger nor more abundant in the spring wood, we turn to the third group of this class. We now note the pith rays, and finding them neither broad nor conspicuous, but difficult to distinguish, even with the magnifier, we at once exclude the wood from the first two sections of this group and place it in the third, which is represented by only one kind, cottonwood. Finding the wood very soft, white, and on the longitudinal section with a silky luster, we are further assured that our determination is correct. We may now turn to the list of woods and obtain further information regarding the occurrence, qualities, and uses of the wood.

Sometimes our progress is not so easy; we may waver in what group or section to place the wood before us. In such cases we may try each of the doubtful roads until we reach a point where we find ourselves entirely wrong, and then return and take up another line; or we may anticipate some of the later-mentioned features and finding them apply to our specimen, gain additional assurance of the direction we ought to travel. Color will often help us to arrive at a speedy decision. In many cases, especially with conifers, which are rather difficult to distinguish, a knowledge of the locality from which the specimen comes is at once decisive. Thus, northern white cedar, and bald cypress, and the cedar of the Pacific will be identified, even without the somewhat indefinite criteria given in the key.

KEY TO THE MORE IMPORTANT WOODS OF NORTH AMERICA.

I. Nonporous woods.—Pores not visible or conspicuous on cross section, even with magnifier. Annual rings distinct by denser (dark-colored) bands of summer wood (fig. 37).

II. Ring-porous woods.—Pores numerous, usually visible on cross section without magnifier. Annual rings distinct by a zone of large pores collected in the spring wood, alternating with the denser summer wood (fig. 5).

III. Diffuse-porous woods.—Pores numerous, usually not plainly visible on cross section without magnifier. Annual rings distinct by a fine line of denser summer-wood cells, often quite indistinct; pores scattered through annual ring; no zone of collected pores in spring wood (fig. 6).

NOTE.—The above-described three groups are exogenous, i. e., they grow by adding annually wood on their circumference. A fourth group is formed by the endogenous woods, like yuccas and palms, which do not grow by such additions.

I. Nonporous Woods.

(Includes all coniferous woods.)

A. Resin ducts wanting.[1]

1. No distinct heartwood.
    - *a.* Color effect yellowish white: summer wood darker yellowish (under microscope pith ray without tracheids) .... *Firs.*
    - *b.* Color effect reddish (roseate) (under microscope pith ray with tracheids) .... *Hemlock.*
2. Heartwood present, color decidedly different in kind from sapwood.
    - *a.* Heartwood light orange red; sapwood pale lemon; wood heavy and hard .... *Yew.*
    - *b.* Heartwood purplish to brownish red; sapwood yellowish white; wood soft to medium hard light, usually with aromatic odor .... *Red cedar.*
    - *c.* Heartwood maroon to terra cotta or deep brownish red; sapwood light orange to dark amber, very soft and light, no odor; pith rays very distinct, specially pronounced on radial section .... *Redwood.*
3. Heartwood present, color only different in shade from sapwood, dingy-yellowish brown.
    - *a.* Odorless and tasteless .... *Bald cypress.*
    - *b.* Wood with mild resinous odor, but tasteless .... *White cedar.*
    - *c.* Wood with strong resinous odor and peppery taste when freshly cut .... *Incense cedar.*

B. Resin ducts present.

1. No distinct heartwood; color white; resin ducts very small, not numerous .... *Spruce.*
2. Distinct heartwood present.
    - *a.* Resin ducts numerous, evenly scattered through the ring.
        - *a′.* Transition from spring wood to summer wood gradual; annual ring distinguished by a fine line of dense summer-wood cells; color white to yellowish red; wood soft and light .... *Soft pines.*[2]
        - *b′.* Transition from spring wood to summer wood more or less abrupt; broad bands of dark-colored summer wood; color from light to deep orange; wood medium hard and heavy .... *Hard pines.*[2]
    - *b.* Resin ducts not numerous nor evenly distributed.
        - *a′.* Color of heartwood orange-reddish; sapwood yellowish (same as hard pine); resin ducts frequently combined in groups of 8 to 30, forming lines on the cross section (tracheids with spirals), *Douglas spruce.*
        - *b′.* Color of heartwood light russet brown; of sapwood yellowish brown; resin ducts very few, irregularly scattered (tracheids without spirals) .... *Tamarack.*

ADDITIONAL NOTES FOR DISTINCTIONS IN THE GROUP.

Spruce is hardly distinguishable from fir except by the existence of the resin ducts, and microscopically by the presence of tracheids in the medullary rays. Spruce may also be confounded with soft pine, except for the heartwood color of the latter and the larger, more frequent, and more readily visible resin ducts.

In the lumber yard, hemlock is usually recognized by color and the slivery character of its surface. Western hemlocks partake of this last character to a less degree.

Microscopically the white pine can be distinguished by having usually only one large pit, while spruce shows three to five very small pits in the parenchyma cells of the pith ray communicating with the tracheid.

The distinction of the pines is possible only by microscopic examination. The following distinctive features may assist in recognizing, when in the log or lumber pile, those usually found in the market:

The light straw color, combined with great lightness and softness, distinguishes the white pines (white pine and sugar pine) from the hard pines (all others in the market), which may also be recognized by the gradual change of spring wood into summer wood. This change in hard pines is abrupt, making the summer wood appear as a sharply defined and more or less broad band.

The Norway pine, which may be confounded with the shortleaf pine, can be distinguished by being much lighter and softer. It may also, but more rarely, be confounded with heavier white pine but for the sharper definition of the annual ring, weight, and hardness.

The longleaf pine is strikingly heavy, hard, and resinous, and usually very regular and narrow ringed, showing little sapwood, and differing in this respect from the shortleaf pine and loblolly pine, which usually have wider rings and more sapwood, the latter excelling in that respect.

The following convenient and useful classification of pines into four groups, proposed by Dr. H. Mayr, is based on the appearance of the pith ray as seen in a radial section of the spring wood of any ring:

Section I. Walls of the tracheids of the pith ray with dentate projections.

a. One to two large, simple pits to each tracheid on the radial walls of the cells of the pith ray.—Group 1. Represented in this country only by *P. resinosa.*

b. Three to six simple pits to each tracheid, on the walls of the cells of the pith ray. Group 2. *P. taeda, palustris,* etc., including most of our "hard" and "yellow" pines.

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[1] To discover the resin ducts a very smooth surface is necessary, since resin ducts are frequently seen only with difficulty, appearing on the cross section as fine whiter or darker spots, normally scattered singly, rarely in groups, usually in the summer wood of the annual ring. They are often much more easily seen on radial, and still more so on tangential sections, appearing there as fine lines or dots of open structure of different color or as indentations or pin scratches in a longitudinal direction.

[2] Soft and hard pines are arbitrary distinctions and the two not distinguishable at the limit.

Section II. Walls of tracheids of pith ray smooth, without dentate projections.

a. One or two large pits to each tracheid on the radial walls of each cell of the pith ray.—Group 3. *P. strobus*, *lambertiana*, and other true white pines.

b. Three to six small pits on the radial walls of each cell of the pith ray.—Group 4. *P. parryana*, and other nut pines, including also *P. balfouriana*.

II. Ring-porous Woods.

[Some of Group D and cedar elm imperfectly ring-porous.]

A. Pores in the summer wood minute, scattered singly or in groups, or in short broken lines, the course of which is never radial.

1. Pith rays minute, scarcely distinct.
   - *a*. Wood heavy and hard; pores in the summer wood not in clusters.
     - *a'*. Color of radial section not yellow .... *Ash.*
     - b'. Color of radial section light yellow; by which, together with its hardness and weight, this species is easily recognized .... *Osage orange.*
   - *b*. Wood light and soft; pores in the summer wood in clusters of 10 to 30 .... *Catalpa.*
2. Pith rays very fine, yet distinct; pores in summer wood usually single or in short lines; color of heartwood reddish brown, of sapwood yellowish white; peculiar odor on fresh section .... *Sassafras.*
3. Pith rays fine, but distinct.
   - *a*. Very heavy and hard; heartwood yellowish brown .... *Black locust.*
   - *b*. Heavy; medium hard to hard.
     - *a'*. Pores in summer wood very minute, usually in small clusters of 3 to 8; heartwood light orange brown .... *Red mulberry.*
     - *b'*. Pores in summer wood small to minute, usually isolated; heartwood cherry red .... *Coffee tree.*
4. Pith rays fine but very conspicuous, even without magnifier; color of heartwood red, of sapwood pale lemon .... *Honey locust.*

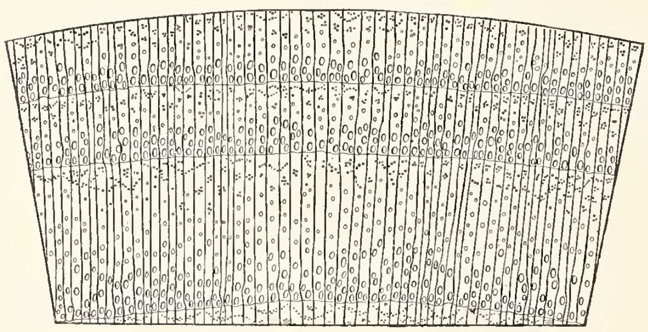


Fig. 7.—Wood of coffee tree.

B. Pores of summer wood minute or small, in concentric wavy and sometimes branching lines, appearing as finely feathered hatchings on tangential section.

1. Pith rays fine, but very distinct; color greenish white; heartwood absent or imperfectly developed. *Hackberry.*
2. Pith rays indistinct; color of heartwood reddish brown, sapwood grayish to reddish white .... *Elms.*

C. Pores of summer wood arranged in radial branching lines (when very crowded radial arrangement somewhat obscured).

1. Pith rays very minute, hardly visible .... *Chestnut.*
2. Pith rays very broad and conspicuous .... *Oak.*

D. Pores of summer wood mostly but little smaller than those of the spring wood, isolated and scattered; very heavy and hard woods. The pores of the spring wood sometimes form but an imperfect zone. (Some diffuse-porous woods of groups A and B may seem to belong here.)

1. Fine concentric lines (not of pores) as distinct, or nearly so, as the very fine pith rays; outer summer wood with a tinge of red, heartwood light reddish brown .... *Hickory.*
2. Fine concentric lines, much finer than the pith rays; no reddish tinge in summer wood, sapwood white, heartwood blackish .... *Persimmon.*

Additional notes for distinctions in the group.

Sassafras and mulberry may be confounded but for the greater weight and hardness and the absence of odor in the mulberry; the radial section of mulberry also shows the pith rays conspicuously.

Honey locust, coffee tree, and black locust are also very similar in appearance. The honey locust stands out by the conspicuousness of the pith rays, especially on radial sections, on account of their height, while the black locust is distinguished by the extremely great weight andhardness, together with its darker brown color.

The ashes, elms, hickories, and oaks may, on casual observation, appear to resemble one another on account of the pronounced zone of porous spring wood. The sharply defined large pith rays of the oak exclude these at once; the wavy lines of pores in the summer wood, appearing as conspicuous, finely feathered hatchings on tangential section, distinguish the elms; while the ashes differ from the hickory by the very conspicuously defined zone of spring-wood pores, which in hickory appear more or less interrupted. The reddish hue of the hickory and the more or less brown hue of the ash may also aid in ready recognition. The smooth, radial surface of split hickory will readily separate it from the rest.

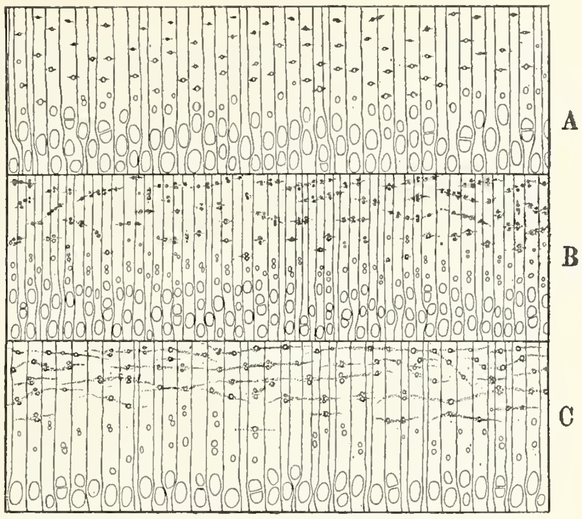


FIG. 8.—Wood of ash: *A*, black ash; *B*, white ash; *C*, green ash.

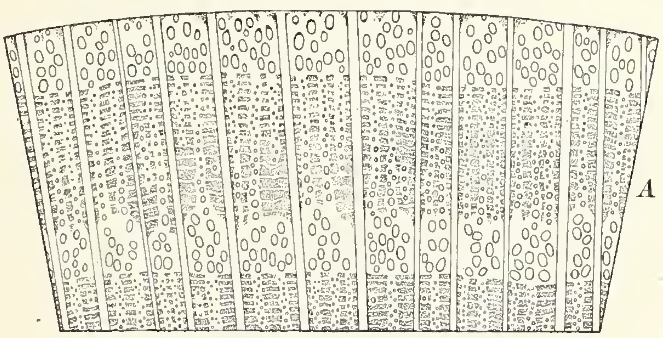


FIG. 9.—Wood of red oak. (For white oak see fig. 5.)

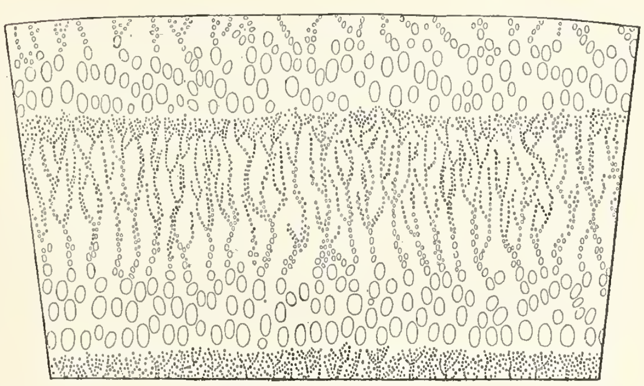


FIG. 10.—Wood of chestnut.

The different species of ash may be identified as follows:

1. Pores in the summer wood more or less united into lines.
   a. The lines short and broken, occurring mostly near the limit of the ring........................ *White ash.*
   b. The lines quite long and conspicuous in most parts of the summer wood........................ *Green ash.*

2. Pores in the summer wood not united into lines, or rarely so.
   - *a*. Heartwood reddish brown and very firm .... *Red ash.*
   - *b*. Heartwood grayish brown, and much more porous .... *Black ash.*

In the oaks, two groups can be readily distinguished by the manner in which the pores are distributed in the summer wood. In the white oaks the pores are very fine and numerous and crowded in the outer part of the summer wood, while in the black or red oaks the pores are larger, few in number, and mostly isolated. The live oaks, as far as structure is concerned, belong to the black oaks, but are much less porous, and are exceedingly heavy and hard.

III. Diffuse-porous Woods.

[A few indistinctly ring-porous woods of Group II, D, and cedar elm may seem to belong here.]

A. Pores varying in size from large to minute; largest in spring wood, thereby giving sometimes the appearance of a ring-porous arrangement.
   1. Heavy and hard; color of heartwood (especially on longitudinal section) chocolate brown .... *Black walnut.*
   2. Light and soft; color of heartwood light reddish brown .... *Butternut.*

B. Pores all minute and indistinct; most numerous in spring wood, giving rise to a lighter colored zone or line (especially on longitudinal section), thereby appearing sometimes ring porous; wood hard, heartwood vinous reddish; pith rays very fine, but very distinct. (See also the sometimes indistinct ring-porous cedar elm, and occasionally winged elm, which are readily distinguished by the concentric wavy lines of pores in the summer wood) .... *Cherry.*

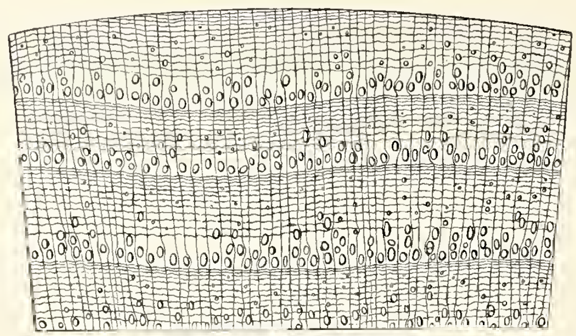


Fig. 11.—Wood of hickory.

C. Pores minute or indistinct, neither conspicuously larger nor more numerous in the spring wood and evenly distributed.
   1. Broad pith rays present.
      - *a*. All or most pith rays broad, numerous, and crowded, especially on tangential sections, medium heavy and hard, difficult to split .... *Sycamore.*
      - *b*. Only part of the pith rays broad.
         - *a'*. Broad pith rays well defined, quite numerous; wood reddish-white to reddish .... *Beech.*
         - *b'*. Broad pith rays not sharply defined, made up of many small rays, not numerous. Stem furrowed, and therefore the periphery of section, and with it the annual rings, sinuous, bending in and out, and the large pith rays generally limited to the furrows or concave portions. Wood white, not reddish .... *Blue beech.*
   2. No broad pith rays present.
      - *a*. Pith rays small to very small, but quite distinct.
         - *a'*. Wood hard.
            - *a''* Color reddish white, with dark reddish tinge in outer summer wood .... *Maple.*
            - *b''*. Color white, without reddish tinge .... *Holly.*
         - *b'*. Wood soft to very soft.
            - *a''*. Pores crowded, occupying nearly all the space between pith rays.
               - *a'''*. Color yellowish white, often with a greenish tinge in heartwood .... *Tulip poplar, Cucumber tree.*
               - *b'''*. Color of sapwood grayish, of heartwood light to dark reddish brown .... *Sweet gum.*
            - *b''*. Pores not crowded, occupying not over one-third the space between pith rays; heartwood brownish white to very light brown .... *Basswood.*
      - *b*. Pith rays scarcely distinct, yet if viewed with ordinary magnifier, plainly visible.
         - *a'*. Pores indistinct to the naked eye.
            - *a''*. Color uniform pale yellow; pith rays not conspicuous even on the radial section .... *Buckeye.*
            - *b''*. Sapwood yellowish gray, heartwood grayish brown; pith rays conspicuous on the radial section .... *Sour gum*
         - *b'*. Pores scarcely distinct, but mostly visible as grayish specks on the cross section; sapwood whitish, heartwood reddish .... *Birch.*

D. Pith rays not visible or else indistinct, even if viewed with magnifier.

1. Wood very soft, white, or in shades of brown, usually with a silky luster .... *Cottonwood (poplar)*.

ADDITIONAL NOTES FOR DISTINCTIONS IN THE GROUP.

Cherry and birch are sometimes confounded. The high pith rays on the cherry on radial sections readily distinguish it; distinct pores on birch and spring-wood zone in cherry as well as the darker vinous-brown color of the latter will prove helpful.

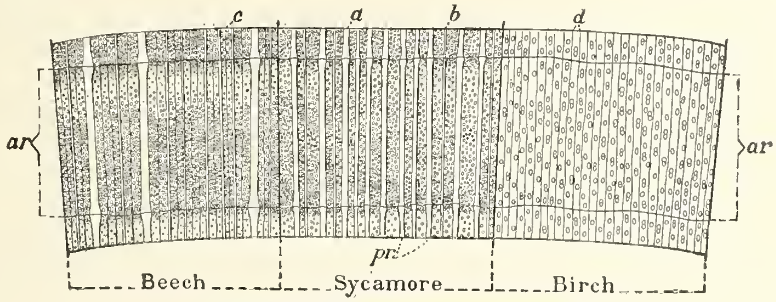


FIG. 12.—Wood of beech, sycamore, and birch.

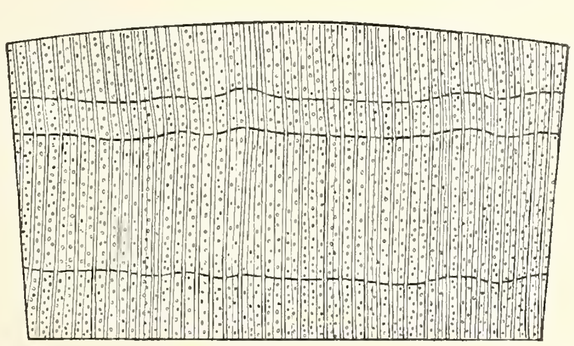


FIG. 13.—Wood of maple.

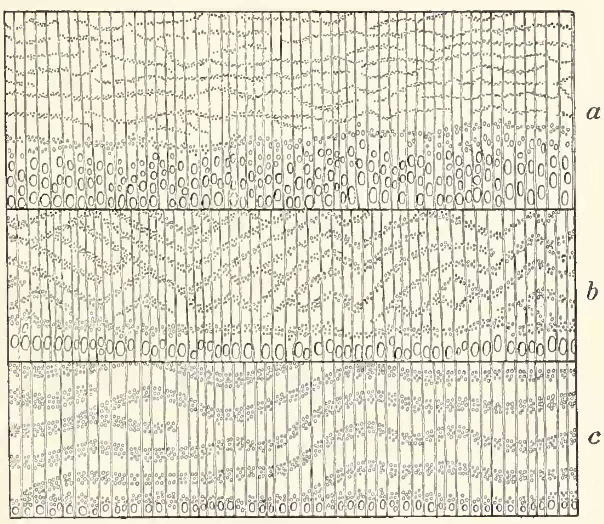


FIG. 14.—Wood of elm. *a* red elm; *b* white elm; *c* winged elm.

Two groups of birches can be readily distinguished, though specific distinction is not always possible.

1. Pith rays fairly distinct, the pores rather few and not more abundant in the spring wood; wood heavy, usually darker .... *Cherry birch and yellow birch*.
2. Pith rays barely distinct, pores more numerous and commonly forming a more porous spring-wood zone; wood of medium weight .... *Canoe or paper birch*.

The species of maple may be distinguished as follows:

1. Most of the pith rays broader than the pores and very conspicuous .... *Sugar maple*.

2. Pith rays not or rarely broader than the pores, fine but conspicuous.
   a. Wood heavy and hard, usually of darker reddish color and commonly spotted on cross section.. *Red maple.*
   b. Wood of medium weight and hardness, usually light colored.............................. *Silver maple.*

Red maple is not always safely distinguished from soft maple. In box elder the pores are finer and more numerous than in soft maple.

The various species of elm may be distinguished as follows:

1. Pores of spring wood form a broad band of several rows; easy splitting, dark brown heart.......... *Red elm.*
2. Pores of spring wood usually in a single row, or nearly so.
   a. Pores of spring wood large, conspicuously so.. *White elm.*
   b. Pores of spring wood small to minute.
      a'. Lines of pores in summer wood fine, not as wide as the intermediate spaces, giving rise to very compact grain.. *Rock elm.*
      b'. Lines of pores broad, commonly as wide as the intermediate spaces .... *Winged elm.*
   c. Pores in spring wood indistinct, and therefore hardly a ring-porous wood .... *Cedar elm.*

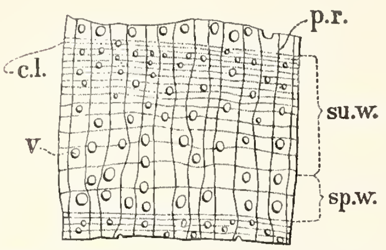


FIG. 15.—Wood of walnut. *p. r.*, pith rays; *c. l.*, concentric lines; *v*, vessels or pores; *su. w.*, summer wood; *sp. w.*, spring wood.

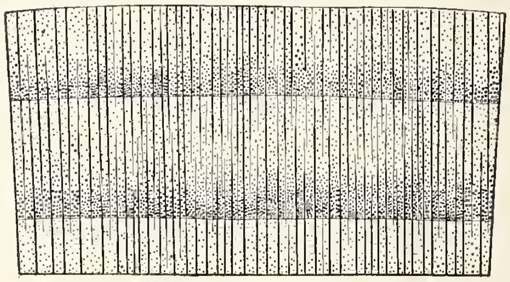


FIG. 16.—Wood of cherry.

STRUCTURE OF THE WOOD OF THE FIVE SOUTHERN PINES.[1]

The wood of these pines is so much alike in appearance and even in minute structure that it can be discussed largely without distinction of species. The distinctions, as far as there are any, have been pointed out in the introduction. Here it is proposed to give in more detail the characteristics of the wood structure.

SAP AND HEART WOOD.

All five species have a distinct sap and heart wood, the sap being light yellow to whitish, the heart yellowish to reddish or orange brown. The line of demarcation between the two is well defined, without any visible transition stage. The location of this line does not as a rule coincide with the line of any annual ring, so that the wood of the same year's growth may be sap on one side of the tree and heart on the other. The difference in this condition may amount to ten or twenty rings, which on one side of the same section will be heart, on the other side sap.

There is considerable variation in the relative width of the two zones as well as the number of rings involved in either and also in the age at which the transition from sap to heart-wood begins. This age was rarely found to be below twenty years; as a rule the transformation begins in young trees when the particular section of the tree is between twenty and twenty-five years old, but the progress of heart formation does not keep pace with the annual growth, being more and more retarded as the tree grows older, so that while in a section twenty-five years old twenty-two rings may be sapwood, at thirty-five years the sapwood will comprise only thirty rings; at forty-five years, forty rings; at eighty years, fifty rings; and in sections two hundred years old the outer eighty to one hundred rings will still be sap. A young tree of longleaf pine (No. 22) was, for instance, found to show the following relations:

Section.	Height from stump.	Age of section.	Rings of sap.
	Feet.	*Years.*	*Number.*
III	6	46	40
IV	14	38	33
VII	22	30	27
IX	30	24	23
XII	42	18	17

[1] Reprinted from Bulletin 13.

The change from sap to heart wood begins earlier in young trees than in the younger portions of older trees; in these latter, sections thirty-six and forty years old are quite commonly found still entirely made up of sapwood, while in young trees, as stated above, the change begins before the age of thirty years.

The progress of the transformation is somewhat influenced by the rate of growth; it is slower in slow-growing trees and usually also on the slower-growing radius, i. e., there are more rings of sapwood. The width of the sapwood, on the other hand, stands in relation to the rate of growth in an opposite manner; it is wider in young and thrifty than in old and stunted trees, and widest along the greatest radius of any section; similarly, it is wider in the faster-growing loblolly, Cuban, and spruce pines than in the slow-growing longleaf.

Besides being of a lighter color the sapwood differs from the heartwood in several respects. Its resin is limpid and oozes out of the pores or resin ducts of any fresh cut; that of the heartwood does not flow, except in rare cases, from saturated pieces or "light wood." The sapwood contains much less rosin—both rosin and turpentine—than the heartwood. Thus in a section of longleaf the sapwood contained only 0.2 per cent of turpentine and 1 per cent of rosin, while the heart contained from 2 to 4 per cent of turpentine and 12 to 24 per cent of rosin, and though this is an extreme case the heart generally has three to five times as much resinous matter as the sap. The fresh sapwood contains three to five times as much free water as the heartwood and is, even when seasoned, more hygroscopic and subject to relatively greater shrinkage than the heart. This capacity for taking up water readily is probably one of the reasons why sapwood decays more readily. In addition, the parenchyma cells of the medullary rays and resin ducts (see further on) contain, at least in the outer parts of the sapwood, living protoplasm and reserve food materials which are readily seized upon by fungi which cause "bluing" and decay. Such living tissue does not exist in the heartwood. The heartwood in old logs generally is heavier than the sapwood. This is not due to any later thickening or growth of its cell walls, after their original formation, but is due chiefly to two causes:

1. The heartwood of old logs was formed when the tree was younger, and made, naturally, heavier wood.

2. The accumulation of resin in the heart already referred to increases often very considerably the weight of the heartwood.

In the same way the sapwood of old logs, such as supply the sawmills, is weaker than the heartwood of the same logs, but this is not because the wood is in the sapwood condition, but because it is lighter and its summerwood per cent smaller, being, as stated before, the product of old age, when heavy and strong wood is no longer formed. Chemically the wood substance of sapwood is practically like that of heartwood; the coloring substances which permeate the cell walls in heartwood appear to be infiltrations, i. e., deposited in the walls from solutions; they are insignificant in amount, and their true nature, especially the processes leading to their formation, are not yet fully understood. The most modern views which consider these coloring bodies or heartwood substances as products of oxidation of tannin still require confirmation.

ANNUAL RINGS.

The layers of growth, known and appearing on any cross section as annual rings, show very distinctly in the wood of these pines. In a section 8 or 10 feet from the ground the rings are widest at the center, of considerable width for the first thirty to fifty rings, the period of most rapid growth in height; then they grow more and more narrow toward the periphery. In the last sixty to one hundred rings of very old logs the decrease is very small, the rings remaining practically of the same width. The same year's growth is usually wider in the upper part of the stem, both in young and old trees, but the average width of the rings is naturally greater in the upper part only of young trees; in old and also in stunted trees it is smaller, since in these the upper portions do not share in the more rapid growth of the early years.

Rings over half an inch wide are frequently seen in loblolly and occur in spruce pine; rings one-fourth of an inch in width occur in very thrifty saplings of all five species, but the average width of the rings for sapling timber is usually less than one-fourth of an inch, commonly one-eighth. In trees over one hundred years old it drops to one-twelfth of an inch and even below. The average

width of the rings is normally smallest in longleaf pine, being one-twenty-fifth of an inch and less. (See also tables and diagrams of rate of growth in the introduction, as well as in the several monographs.)

The influence of orientation on the width of the rings is completely obscured by other, more potent influences, so that sometimes the radius on the north side, other times that of some other side, is the greatest; and it is a common observation to see this relation vary within wide limits, even in the trunk of the same tree.

Stunted trees of longleaf pine over one hundred years old with an average width of ring of one-fiftieth of an inch are frequently met with in old timber; of the other species no such trees were observed. The decrease of the width of the rings from center to periphery is never perfectly uniform. Not only do consecutive rings differ within considerable limits, but frequently zones of narrower rings, including thirty or more years' growth, disturb the general regularity. Where these zones consist of very narrow rings, one-fiftieth of an inch or less, the wood is of distinctly lighter color and weight. Since the value of this class of wood depends not only on its strength and stiffness but also on the fineness of its rings (grain), in so far as the grain influences both the appearance and the ease of shaping as well as other mechanical properties, the width of the annual ring is of great importance, from a technical point of view, the finer-ringed (grained) wood of the same weight always deserving and mostly receiving preference.

The rings of the limbs are narrower than the corresponding rings of the stem. Moreover, they are usually of different widths on the upper and lower side of the same branch, those of the latter excelling in width those of the former. Frequently the wider lower part of a ring of a branch appears like a "lune" on the cross section, quite wide (one-eighth of an inch and more) in its lower median part, and scarcely visible, often entirely fading out on the upper side. This difference is commonly accentuated by the appearance of the wood itself. In the upper part the wood of the wing is normal and light colored, owing to a very small summerwood per cent; on the lower wide part, the "lune," the wood is commonly of reddish color, either even throughout the entire width of the ring, or else in several varicolored bands, which give the appearance of two or more separate ill-defined rings. Sometimes the earliest formed springwood is included in this unusual coloration, at other times only the median portion of the ring. This "red wood," as it has been termed by the French and German writers, is composed of very thick walled cells and increases markedly the weight of the wood, so that the wood of the side containing it is usually much the heaviest. It is of interest that the several "lunes" in any cross section occur rarely, if ever, exactly one above the other, but commonly the radius passing through the middle of one "lune" makes an angle of 20 to 40 degrees with the radius passing through the middle of another "lune." Often successive "lunes" show considerable deviation in position and commonly differ in width or degree of development. Accepting the most recent explanation of this phenomenon as expressed by Hartig and Cieslar,[1] it would appear that the formation of these broad "lunes" of especially strong cells is due to pressure-stimulus on the growing cambium, caused by the weight of the limb and its peculiar position, increased at all times by movements of the limb due to the wind. Moreover it seems that the formation of one well-developed "lune" relieves for a time the pressure, and with it the necessity for a repetition of this formation. These "lunes" are most conspicuous in the limbs of these pines near the trunk, and disappear at variable distances from the trunk and with them disappears the eccentricity and the difference in appearance and weight of the wood of the limbs. Immediately at the junction of limb and stem the pressure is constant, and the result is the formation of almost uniformly thick-walled tissue in all parts of the ring, giving to the "knot" its great weight and hardness.

Lunes similar to those of the limb are frequently observed in the stems of small trees; wherever this has been noted it was found on the underside of a leaning or curved portion.[2] Occasionally such a "lune" extends for 12 and more feet up and down.

Quite distinct from this modification of the annual ring is another modification frequently seen, especially in young trees, giving rise to so-called "false" rings. It consists in the appearance of

[1] A. Cieslar, "Rotholz d. Fichte," Centralblatt f. d. g. Forstwesen 1896, p. 149, and Robert Hartig "Das Rothholz der Fichte" in Forstlich-naturwissenschaftliche Zeitschrift, 1896, p. 165.

[2] Cieslar produced them at will by bending young spruce saplings.

one or more, rarely two, dark colored lines, which precede the true summerwood band of the ring. These lines, resembling the summerwood in color and composed like it of think-walled cells, follow the true springwood of the year and are separated from the summerwood and from each other (if there are more than one) by a light-colored line resembling springwood. While occasionally this is somewhat misleading in counting the rings, a moderate magnification usually suffices to distinguish the real character of the tissues, as described later on. A more serious difficulty arises in very old, slowly growing trees, where the ring sometimes is represented by only one to three cells (see fig. 18) and occasionally disappears, i. e., is entirely wanting in some parts of the cross section. Generally these cases, due to various causes, are too rare to seriously interfere in the establishment of the age of a tree.

SPRING AND SUMMER WOOD.

The difference between spring and summer wood is strongly marked in these pines, the transition from the former to the latter being normally abrupt and giving to the annual ring the appearance of two sharply defined bands. (See figs. 17 and 22.) In wide rings the transition

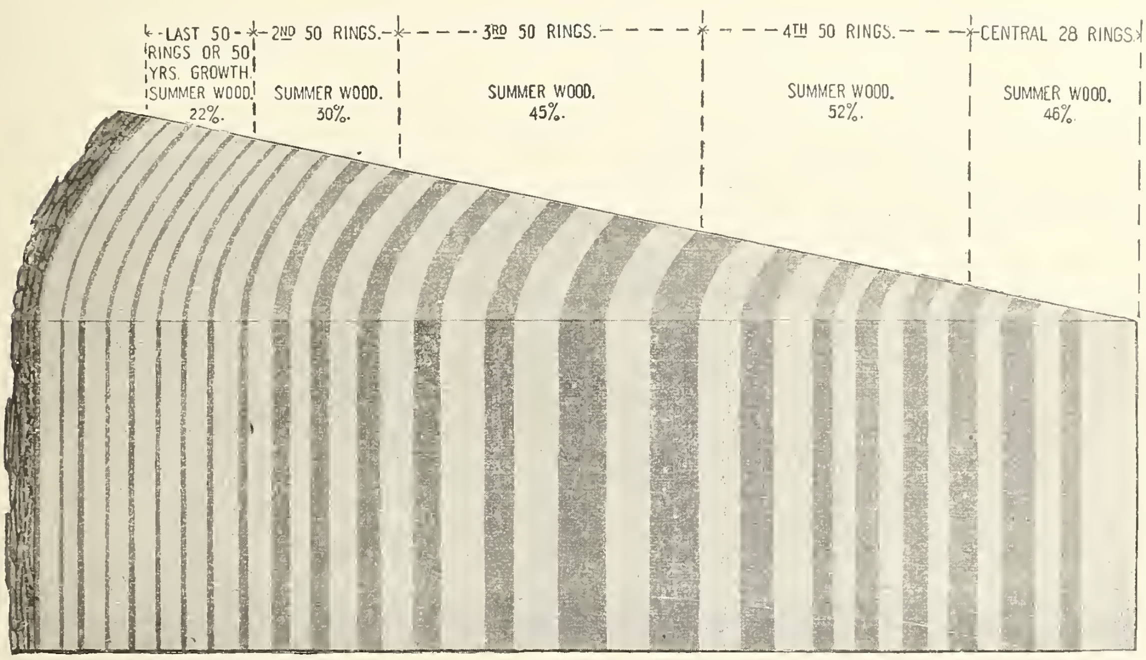


FIG. 17—Variation of summerwood per cent from pith to bark.

is sometimes gradual. The springwood is light colored, has a specific gravity of about 0.40, and thus weighs somewhat less than half as much as the darker summerwood, with a specific gravity of about 0.90 to 1.05, so that the weight and with it the strength of the wood is greater, the larger the amount of summerwood. (See figs. 17 and 19.)

The absolute width of the summerwood varies generally with the width of the ring (see diagram, fig. 19), i. e., the wider the ring the wider the summerwood band. It decreases in a cross section of an old log from near the pith to the periphery, and in the same layer, from the stump to the top of the tree. Where the growth of the stem is very eccentric, the wood along the greater radius has the greatest proportion of summerwood; thus, in a disk of longleaf, for instance, there is on the north side a radius of 152 mm. with 27 per cent summerwood; on the south side a radius of 98 mm. and a summerwood per cent of only 20 per cent. In the stump section the great irregularity in the contour of the rings is accompanied by a corresponding irregularity in the outline of the summerwood.

The summerwood generally forms less than half of the total volume of the whole log (see fig. 17); it forms a greater part of the coarse-grained wood which was grown while the tree was young than in the fine-ringed outer parts of the log, grown in the old age period. It also forms a greater

part in the volume of the butt than of the top log, and thus fully explains the well-known difference in the weight, strength, and value of the various parts of the tree. The following table serves to illustrate this point. The numbers in each line refer to the average values for the same ten annual layers through three sections of the tree at varying height. The figures in *italics* below refer to specific gravity for the same layer. The values for specific gravity were calculated on the basis of allowing a specific gravity of 0.40 for springwood and 0.90 for summerwood, the values for the entire disks as actually observed being given below:

Summerwood per cent and specific gravity in various parts of a tree of longleaf pine.

Rings from periphery.	1 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 to 120	121 to 130	131 to 140	141 to 150	151 to 160	161 to 170	171 to 180	181 to 190	191 to 200	201 to 210	211 to 220	221 to 230	231 to 236	Average for total.
Section I, 3 feet from ground.	39	44	40	42	38	35	45	32	44	66	43	43	52	56	48	46	48	43	47	47	52	45	42	*a*15	45
	.59	*.62*	*.60*	*.61*	*.59*	*.57*	*.62*	*.56*	*.62*	*.73*	*.61*	*.61*	*.66*	*.68*	*.64*	*.63*	*.64*	*.61*	*.63*	*.63*	*.66*	*.62*	*.61*	*.47*	*.625*
Section IV, 35 feet from ground	26	24	25	34	28	24	26	24	35	49	31	33	43	34	40	31	34	33	33	31	22	*b*6	....	....	29
	.53	*.52*	*.52*	*.57*	*.54*	*.52*	*.53*	*.52*	*.57*	*.64*	*.55*	*.56*	*.61*	*.57*	*.60*	*.55*	*.57*	*.56*	*.56*	*.55*	*.51*	*.43*	....	....	*.545*
Section VII, 70 feet from ground	23	16	17	18	18	20	16	20	18	26	21	24	19	19	22	16	18	*c*2	....	....	....	....	....	....	18
	.51	*48*	*.48*	*.49*	*.49*	*.50*	*.48*	*.50*	*.49*	*.53*	*.50*	*.52*	*.49*	*.49*	*.51*	*.48*	*.49*	*.41*	....	....	....	....	....	....	*.490*

a Six rings next to pith. *b* Two rings. *c* One ring.

The observed values of specific gravity for the three sections are 0.700, 0.560, and 0.490, respectively.

It will be noticed that the greatest difference between the calculated and the actual value of specific gravity occurs in the section at the stump. This is fully accounted for by the fact that large amounts of resin, not considered in the values of summerwood per cent, always occur in this portion, adding from 5 to 20 per cent to the weight of the wood.

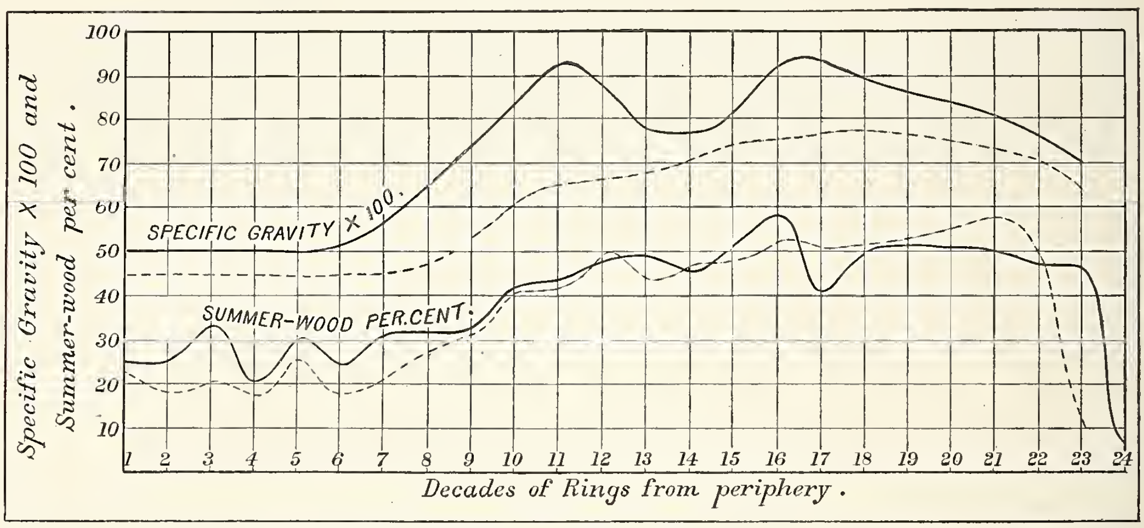


FIG. 18—Variation of specific gravity with summerwood per cent and age of section in longleaf pine, the solid lines referring to a section 3 feet from the ground, the dotted lines to one 14 feet from the ground. (Specific gravity as actually observed on pieces of 1 inch radia extent.)

In stunted trees the summerwood forms nearly as great a per cent of the total volume for the whole tree as in thrifty trees of the same age, but in the stunted growth, or extremely narrow ringed portion of otherwise normal trees, the per cent of summerwood is markedly decreased, a feature which becomes conspicuous in the lighter color of the wood of such portions. (See diagram, fig. 22, A.) Where, on the other hand, the rate of growth in an old tree is suddenly increased by the accessibility of more light, for instance, the summerwood per cent also is disproportionately increased, but this disproportion appears to be more transient, i. e., a decrease in the summerwood per cent sets in sooner than for the rate of growth or the width of the rings. (See fig. 19.) In some of the rapidly grown loblolly and spruce pine the summerwood forms but a small part of the

first ten to twenty years' growth, and in all cases the first few rings about the pith have but little summerwood. In general, the summerwood per cent varies in the several species as well as in the individual with the weight of the wood, which is least in the spruce pine, greatest in Cuban and longleaf pine, and stands between these in loblolly and shortleaf. It furnishes a very useful criterion to distinguish between these groups, and especially to select strong timber.

In the limb, the summerwood is most abundant in the knot (all wood practically partaking of the character of summerwood, at least as far as the thickness of cell walls is concerned) and in the

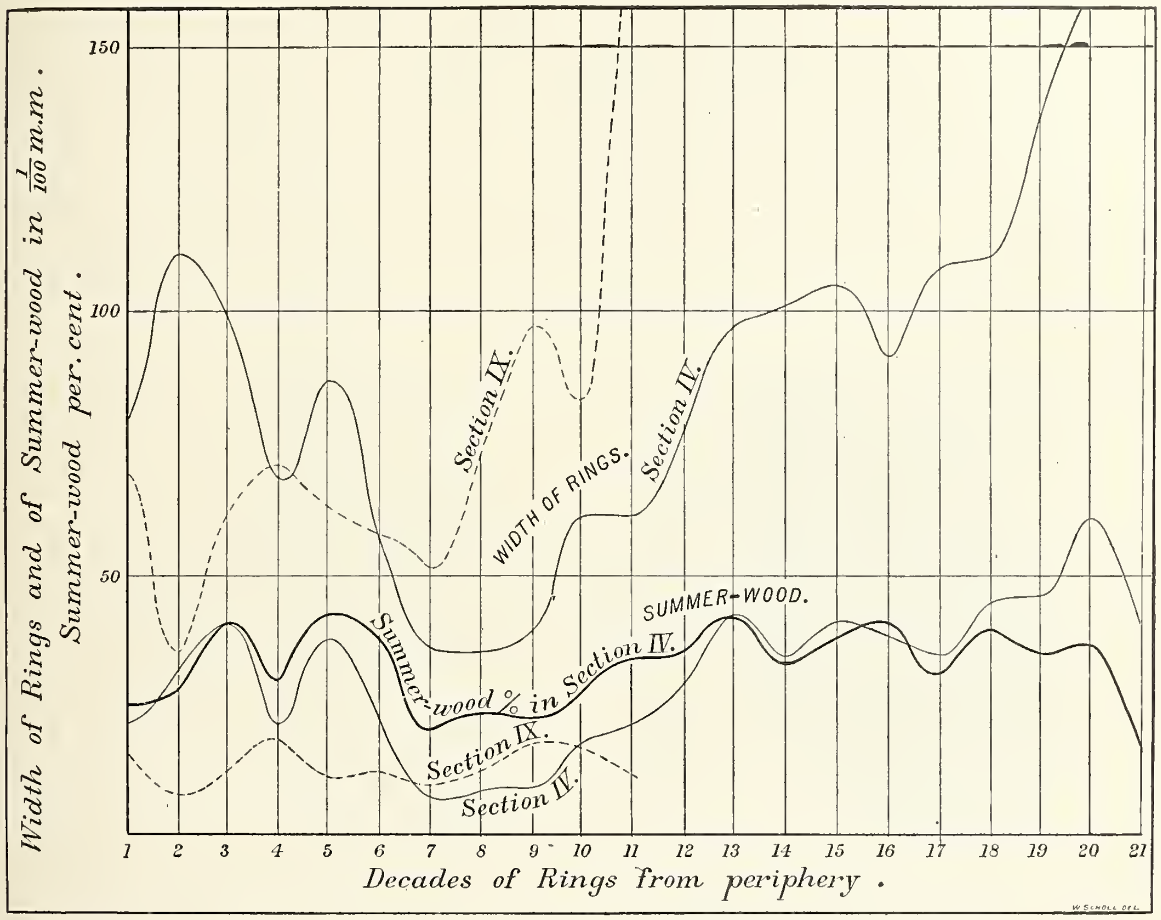


FIG. 19.—Variation of summerwood per cent with rate of growth (width of ring) in tree No. 3, longleaf pine.

NOTE.—Only the heavy line represents summerwood per cent; the others indicate the actual width of the rings (upper pair) and of the band of summerwood (lower pair).

part next to the stem, decreasing with the distance from the trunk. As might be expected, it also forms a larger per cent of the wood of the underside of limbs and the concave portions of bent trunks.

GRAIN OF THE WOOD.

Though usually quite straight grained, the wood of these species is by no means always so. Spiral growth, leading to "cross-grained" lumber, occurs frequently, is usually more pronounced in the basal portions of the tree, and commonly varies from pith to bark in the same log. Wavy grain resembling that of the maple (curly maple) has not been observed, but an irregular wavy grain, due to the fact that the surface of the trunk for many years is covered with small, low eminences, 1 to a few inches across, is frequently seen, especially in longleaf pine, and leads to remarkably pretty patterns. Unfortunately the contrast of spring and summer wood being so very pronounced, the figures are somewhat obtrusive and therefore not fully appreciated.

MINUTE ANATOMY.

The minute structure or histology of the wood of the five species under consideration is that of a group whose position in a general classification of the wood of pines is indicated in the following scheme, suggested by Dr. J. Schroeder, and more completely by Dr. H. Mayr,[1] in which they appear as part of group 2 of Section I.

Section I. Walls of the tracheids of the pith ray, with dentate projections.

- *a*. One to two large, simple pits to each tracheid on the radial walls of the cells of the pith ray.—Group 1. Represented in this country by *P. resinosa*.
- *b*. Three to six simple pits to each tracheid on the walls of the cells of the pith ray.—Group 2. *P. tæda, palustris*, etc., including most of our "hard" and "yellow" pines.

Section II. Walls of tracheids of pith ray smooth, without dentate projections.

- *a*. One or two large pits to each tracheid on the radial walls of each cell of the pith ray.—Group 3. *P. strobus lambertiana*, and other true white pines.
- *b*. Three to six small pits on the radial walls of each cell of the pith ray.—Group 4. *P. parryana*, and other nut pines, including also *P. balfouriana*.

The general features of structure of coniferous woods are represented in the accompanying cut (fig. 20).

The structural elements, as in all pine, are few and simple, and consist of (*a*) tracheids, the common wood fibers, forming over 90 per cent of the volume; (*b*) medullary or pith rays, minute

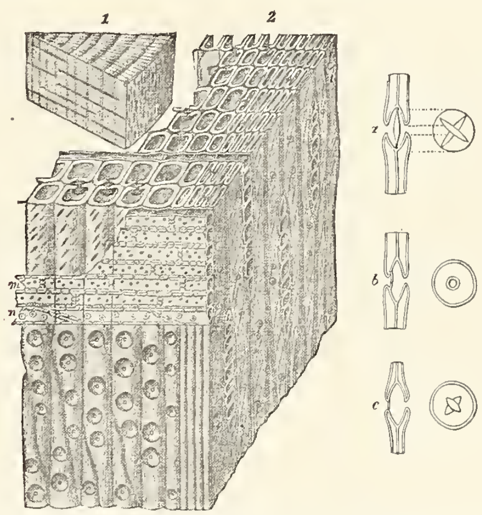


FIG. 20.—Schematic representation of coniferous wood structure: wood of spruce—1, natural size; 2, small part of one ring magnified 100 times. The vertical tubes are wood fibers, in this case all "tracheids;" *m*. medullary or pith ray; *n*, transverse tracheids of pith ray; *a*, *b*, and *c*, bordered pits of the tracheids more enlarged.

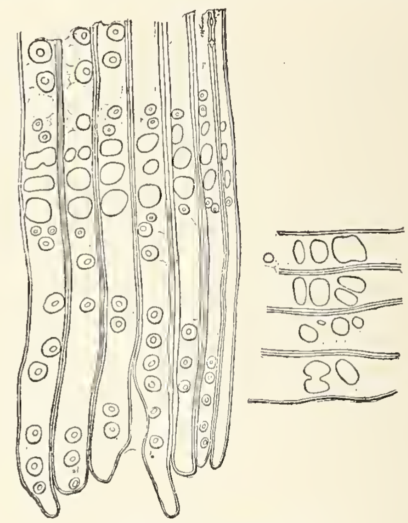


FIG. 21.—Cell endings in pine.

cell aggregates composed of two kinds of cells, scarcely visible without magnifier and then only on the radial section, yet forming about 7 to 8 per cent of the volume and weight of the wood in these species; (*c*) resin ducts, small passages of irregular length surrounded by resin-secreting cells scattered through the wood, but forming two more or less connected systems, one running in the direction of the fibers, the other at right angles to the first, the individual ducts of the latter system always occupying the middle portion of medullary rays.

The tracheids, or common wood fibers, are alike in all five species, and resemble those of other pines: they are slender tubes, 4.5 to 6 mm. (about one-fourth inch) long, forty to one hundred times as long as thick, usually hexagonal in cross section, with sharp or more or less rounded outlines (see Pl. XX), flattened in tangential direction at both ends (see Pl. XX, A*f*), the diameter in radial direction being 45 to 55 μ (about 0.002 inch) in the springwood, and about half that, or 21 to 25 μ, in the summerwood, and in tangential direction about 40 μ, on the average in their

[1] Dr. J. Schroeder, Holz der Coniferen, Dresden, 1872, p. 65; Dr. H. Mayr, Waldungen von Nordamerika, München, 1890, p. 426.

middle. They are arranged in regular radial rows (see Pl. XX), which are continuous through an indefinite number of rings, but the number of rows increasing every year to accommodate the increasing circumference of the growing stem. (See Pl. XX, C *c*.) The fibers of the same row are practically conterminous, i. e., they all have about the same length, though at their ends they are often bent, slightly distorted, and usually separated (see Pl. XX, B *c*; also fig. 21), their neighbors filling out the interspaces. There is no constant difference in the dimensions of these fibers in the different species here considered. In every tree the fibers are shortest and smallest

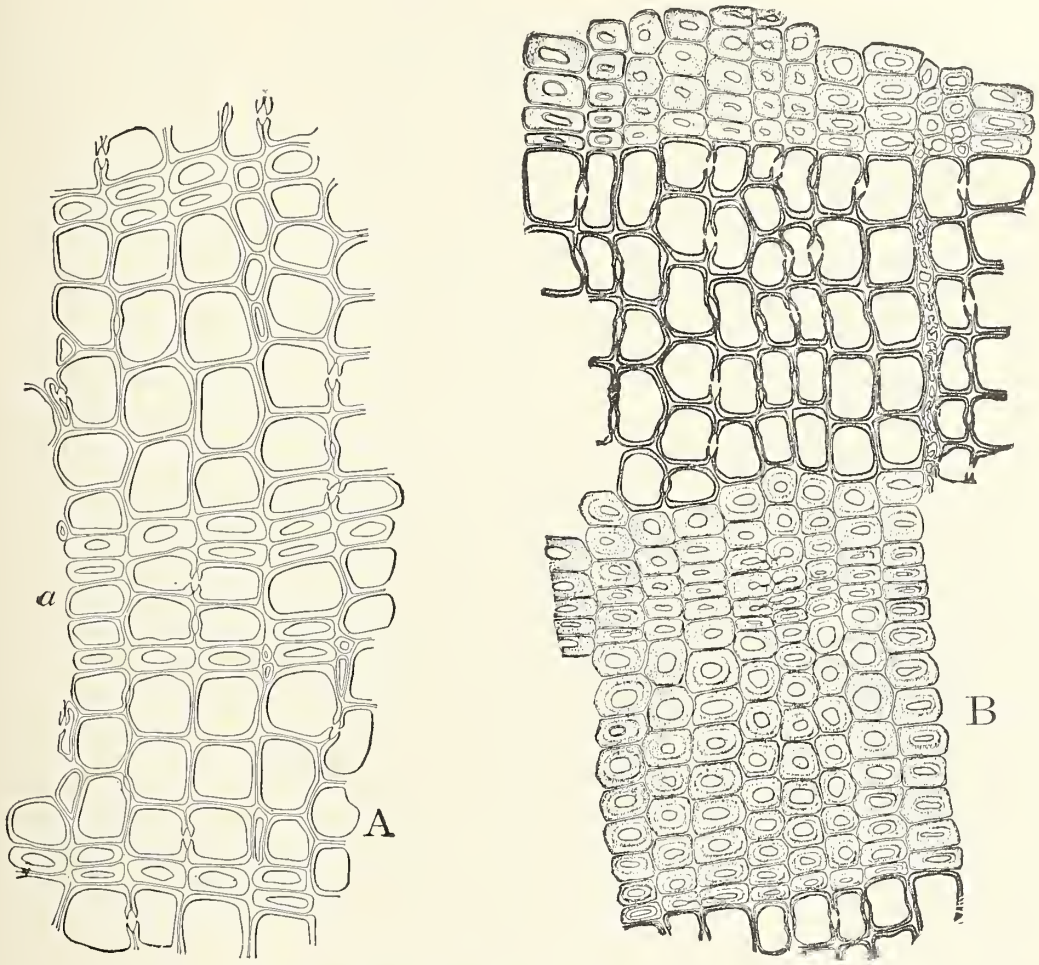


FIG. 22.—Cross section of normal and stunted growth in Longleaf Pine.

near the pith of any section, rapidly increasing in size from the pith outward, and reaching their full size in about the tenth to twentieth ring from the pith. To illustrate: In a section of longleaf pine, 10 feet from the ground, the diameter of the tracheids in radial direction is in μ=0.001 mm.:

Number of rings from center.	Spring-wood.	Summer-wood.	Average.
	μ	μ	μ
1	24	15	24
2	34	23	32
3	45	24	40
4	43	26	36
7	50	26	38
10	52	28	36
24–33	52	28	36
44–53	52	27	37

As usual in conifers, the tracheids are largest in the roots and smallest in the limbs. In these pines, especially in longleaf pine, they are larger in well-grown wood than in that of extremely stunted trees, though very narrow rings in otherwise normal trees do not share this diminutive size of the tracheids. (See fig. 22, A and B, where a few very narrow rings are made up of elements of normal size.)

The following average figures illustrate the difference between wood from very stunted trees and that of normal trees in longleaf pine, of which we give an average from an extensive series examined:

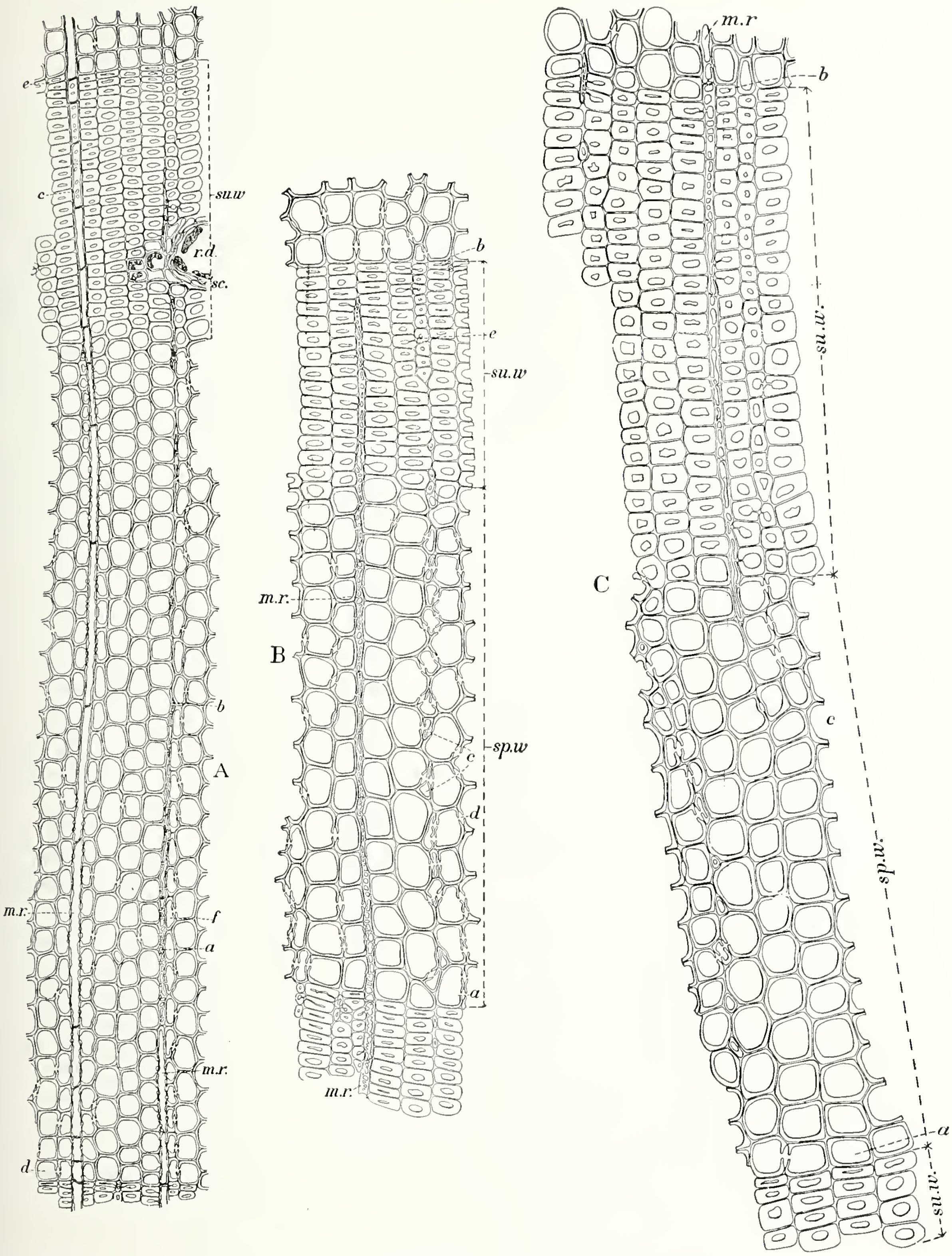
Number of tree.	Age.	Average width of ring.	Radial diameter of tracheids in springwood $\mu = 0.001$ mm.	Character of tree.
		Millimeters.		
4	86	0.4–0.5	31–36	Stunted.
5	60	.4	30–36	Do.
6	70	.4	33–38	Do.
7	68	2.0	52	Normal.

As soon as the average width of the annual rings gets above 0.5 mm. the dimensions of the elements approach the normal. Thus, in trees Nos. 1 and 2, with average width of annual rings 0.5 to 0.6 mm., the average diameter of the tracheids in radial direction is 35 to 48 μ.

Normally, the diameter in radial direction is greatest in the first-formed or inner part of any ring, and decreases even before the summerwood is reached. In narrow rings with an abrupt beginning of the summerwood, so common in these Southern pines, the diameter is quite constant throughout the springwood, but changes, together with the thickness of the wall, quite suddenly with the beginning of the summerwood, thus adding to the sharpness of the outlines of the two parts. (See Pl. XX; also fig. 22, B.) In nearly all sections there is an additional marked decrease in radial diameter in the last 3 to 5 cells of each row, which helps to emphasize the limits of the ring. In the so-called "false" rings, mentioned before, the cells of the false summerwood part resemble those of the normal summerwood. The recognition of the false ring as such rests upon the difference in shape and dimensions of the last cell rows in comparison with those adjoining. In the true summerwood the last cells are much flattened, with small lumen and somewhat reduced walls making a sharp definition toward the springwood of the next ring, which is still further accentuated by the wide lumen and thin wall of the cells of the latter. In the "false" summerwood, on the contrary, the end cells are not flattened, and the cells of the light-colored adjoining zone of wood have but a moderately wide lumen and comparatively thick walls. The fact that the outline is less regular and commonly incomplete—i. e., it does not extend around the entire section—also aids in recognizing the false rings. In the "lunes" of both limb and stem referred to above the fibers are smaller, more rounded in cross section, and commonly exhibit conspicuous intercellular spaces between them. The walls of these are often much thicker than those of the summerwood of the same ring at this point. Since the radial diameter of the fibers of the summerwood is only about half as great as that of the springwood, it is clear that the number of fibers of the summerwood forms a much greater per cent of the total number of fibers than is indicated in the per cent of summerwood given above and based upon its relative width. Thus, in wood having 50 per cent of summerwood there are, in number, twice as many tracheids in the summerwood as in the springwood.

The walls of the cells are generally about 3 to 3½ μ thick in the springwood, while in the summerwood they are 6 to 7 μ thick on the tangential side and 8 to 11 μ thick on the radial side of the fiber. Generally it may be said that the thickness varies inversely as the extent of the wall, i. e., the greater any diameter the thinner the walls parallel to this diameter, which gives the impression that each cell is furnished an equal quantum of material out of which to construct its house and had the tendency of giving an equal amount to each of its four or six sides.

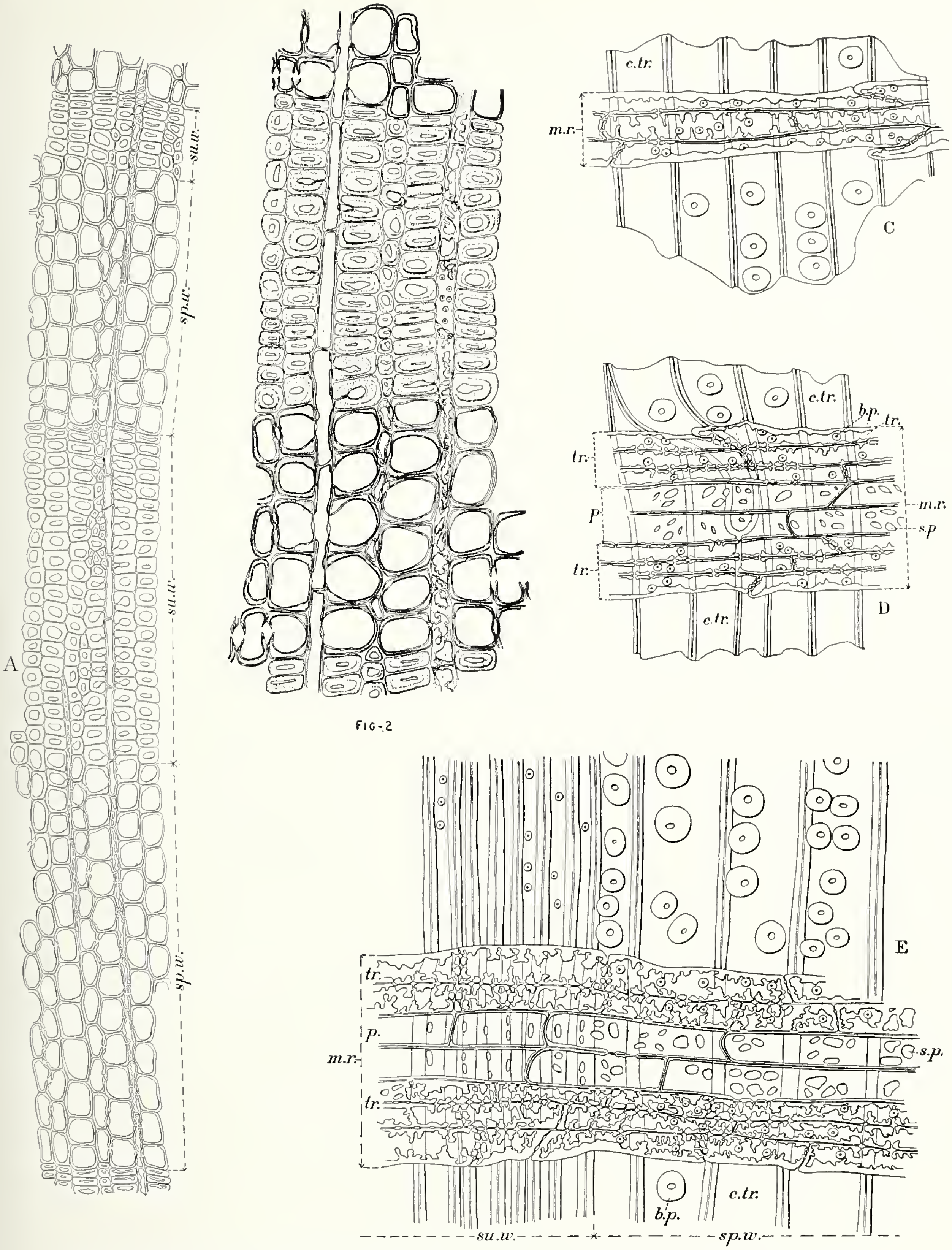
Generally the absolute width of the ring does not affect the thickness of the cell walls, the fibers of wide rings having no thicker walls than those of narrow rings; but when the growth of a tree is unusually suppressed, so that the rings are less than 0.5 mm. (0.02 inch) wide and each row consists of only a few fibers, the walls of the fibers of the summerwood, like those of the last-



TYPICAL CROSS SECTIONS OF PINUS TÆDA, HETEROPHYLLA, AND GLABRA.

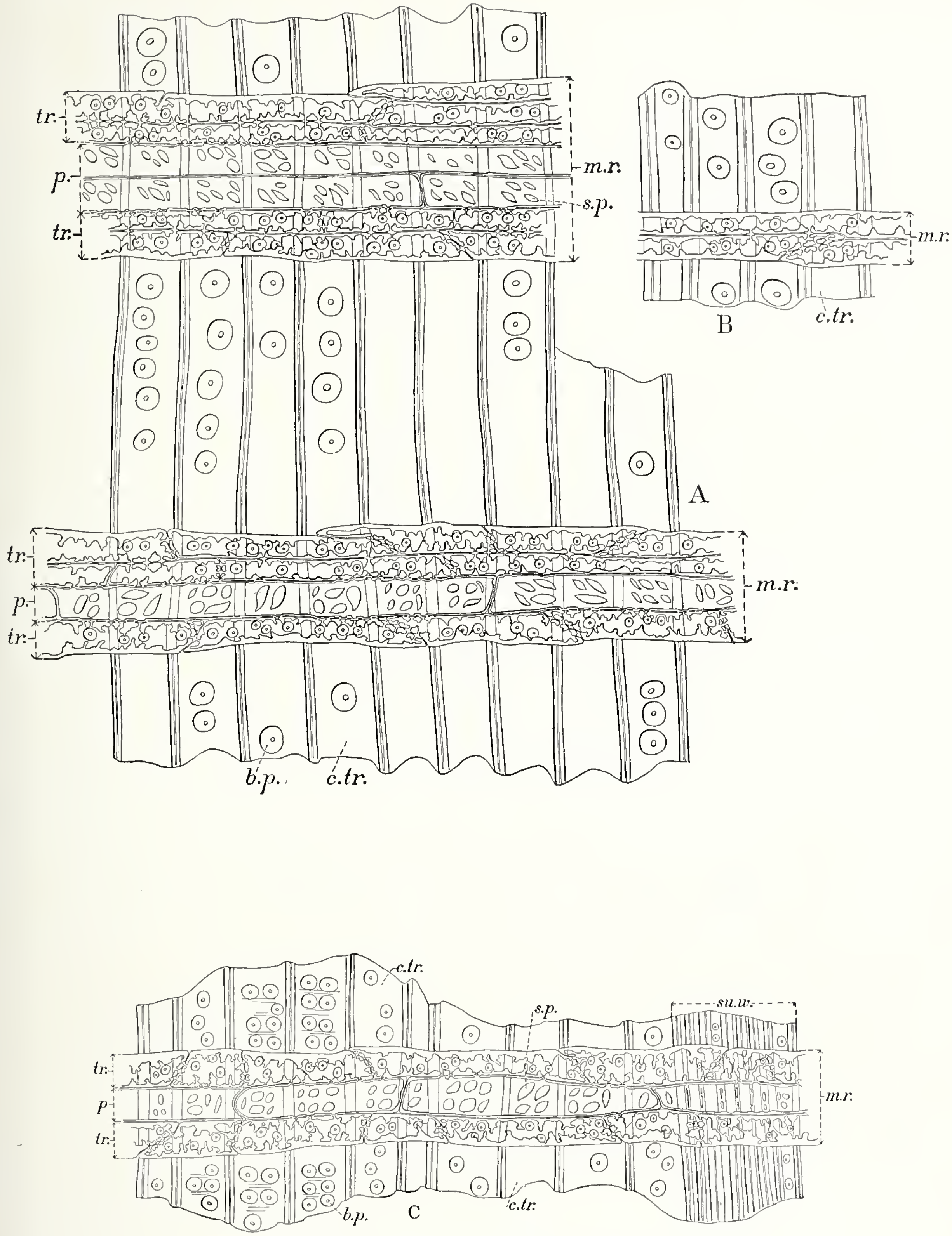
r. d., resin ducts; *s. c.*, secreting cells; *m. r.*, medullary rays; *sp. w.*, spring wood; *su. w.*, summer wood.

A, PINUS TÆDA: *a–b*, transverse tracheids; *c*, simple pits; *d–e*, row of tracheids; *f*, flattened terminal of tracheid.
B, PINUS HETEROPHYLLA: *a–b*, row of tracheids; *c*, terminal of tracheid; *d–e*, bordered pits.
C, PINUS GLABRA: *a–b*, single row of tracheids; *c–b*, same row doubled.



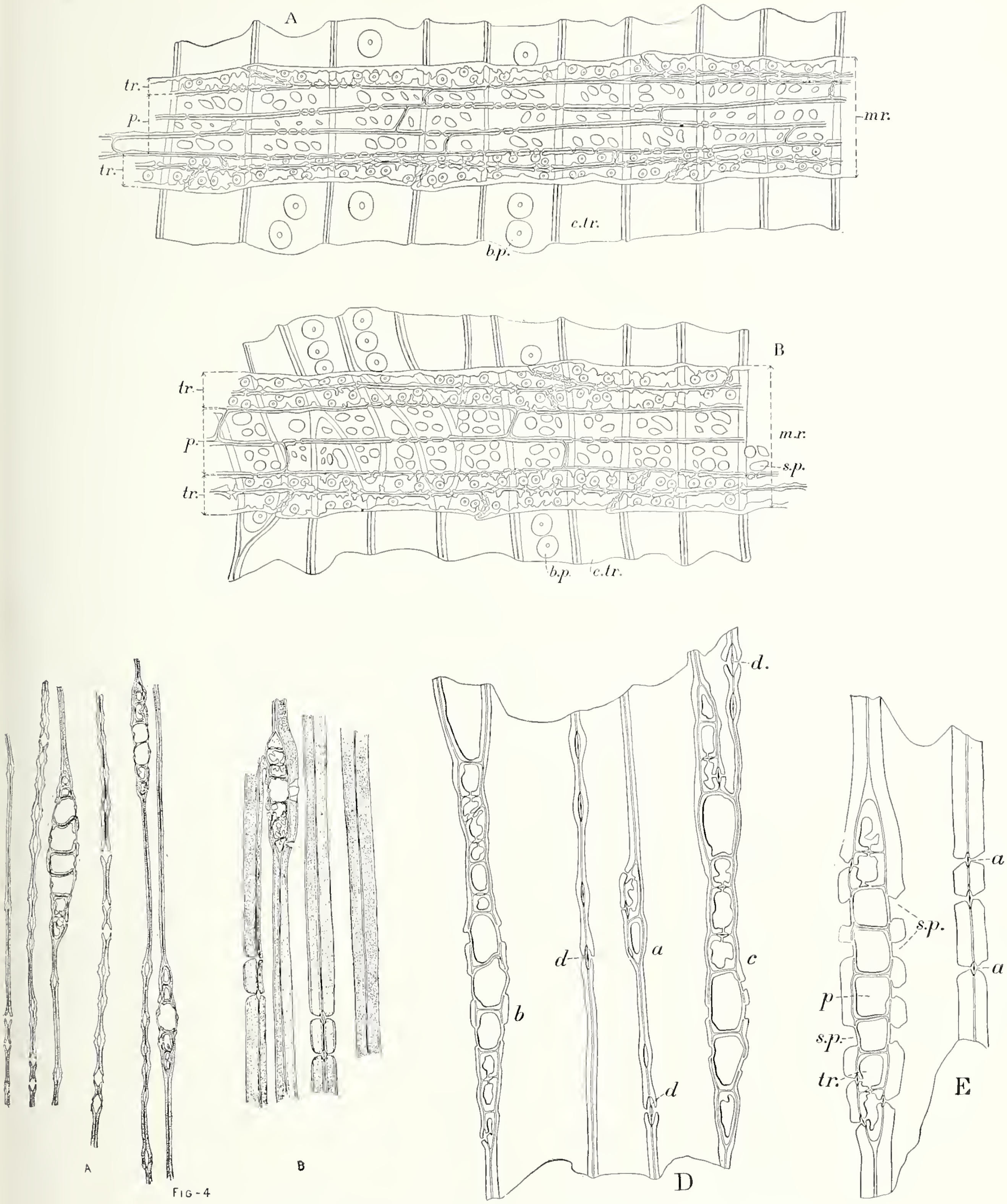
TYPICAL CROSS SECTIONS OF PINUS PALUSTRIS AND ECHINATA, AND RADIAL SECTIONS OF PINUS PALUSTRIS AND GLABRA.

A, PINUS ECHINATA. Cross section of two rings; *sp. w.*, springwood; *su. w.*, summerwood.
B, PINUS PALUSTRIS. Cross section of a very narrow ring. Of the two medullary rays one is cut through a row of parenchyma, the other through a row of tracheids.
C and *D*, PINUS GLABRA. Radial sections; *m. r.*, medullary rays; *tr.*, tracheids of the medullary rays; *p.*, parenchyma of the same; *s. p.*, simple pits leading from the pareuchyma to the neighboring tracheids or common fibers *c. tr.*; *b. p.*, bordered pit. The ray at *C* is made up of tracheids only.
E, PINUS PALUSTRIS. Radial section; lettering as in *D*.
Originals magnified: *A*, $\frac{300}{1}$, the rest $\frac{500}{1}$; illustrations: *A*, $\frac{100}{1}$, the rest $\frac{200}{1}$.



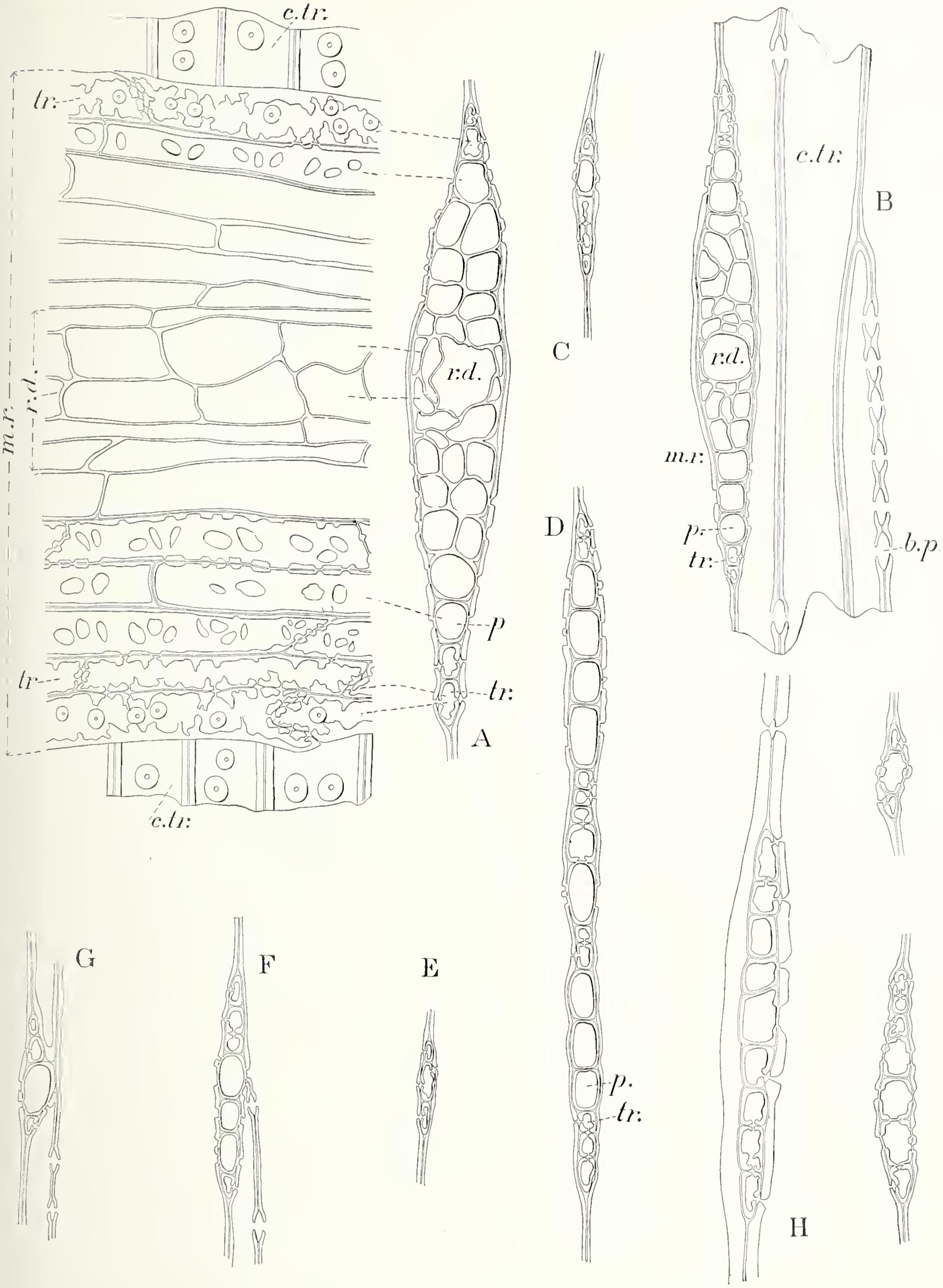
RADIAL SECTIONS OF PINUS ECHINATA AND HETEROPHYLLA.

A and *B*, PINUS ECHINATA. *m. r.*, medullary rays; *p.*, parenchyma of same; *tr.*, transverse tracheids of rays; *s. p.*, simple pits; *b. p.*, bordered pits; *c. tr.*, common tracheids.
C, PINUS HETEROPHYLLA. *su. w.*, summerwood; other letters as in *A*.
Originals magnified $\frac{500}{1}$; illustrations, $\frac{200}{1}$.



RADIAL SECTIONS OF PINUS TÆDA AND TANGENTIAL SECTIONS OF PINUS PALUSTRIS AND ECHINATA.

A and *B*, PINUS TÆDA. Radial sections; *m. r.*, medullary rays; *tr.*, tracheids; *p.*, parenchyma of the rays; *s. p.*, simple pit; *b. p.*, bordered pit; *c. tr.*, common tracheids.
C-E, tangential sections.
C, PINUS PALUSTRIS. Left-hand part in springwood, right-hand portion in summerwood.
D-E, PINUS ECHINATA. *D*, section in springwood; *a-c*, medullary rays; *a*, a small ray composed of tracheids only; *c*, a "triple" ray; *d*, bordered pit showing the membrane in place. *E*, section in summerwood; *a*, bordered pit, other letters as in *A* and *B*.
Magnification of originals, $\frac{500}{1}$; of illustrations: *A* and *B*, $\frac{200}{1}$; *C-E*, $\frac{300}{1}$.



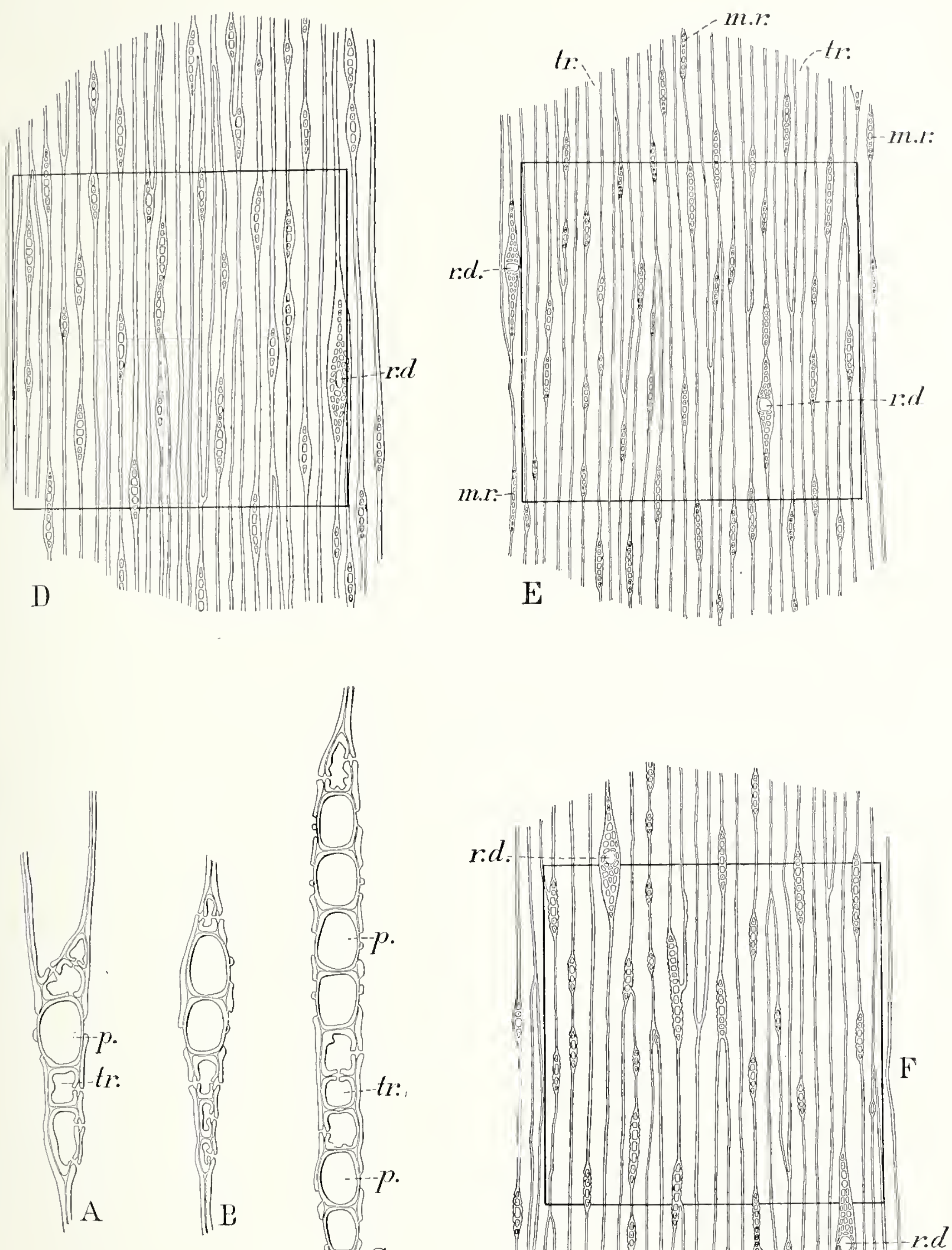
TANGENTIAL SECTIONS OF PINUS TÆDA, HETEROPHYLLA, AND GLABRA.

A, PINUS HETEROPHYLLA. Radial and tangential sections of a transverse resin duct; *r. d.*, resin duct; *m. r.* medullary ray; *tr.*, tracheids of the medullary ray; *p.*, parenchyma cells of the same; *c. tr.*, common tracheids or wood fibers.

B-G, PINUS GLABRA. *B*, tangential section of a transverse resin duct and parts of three fibers; *b. p.*, bordered pit; other letters as above; *C-G*, tangential sections of medullary rays, of which *E* is made up of tracheids only, while *D* is a "triple" ray

H, PINUS TÆDA. Tangential sections of medullary rays in spring and summer wood.

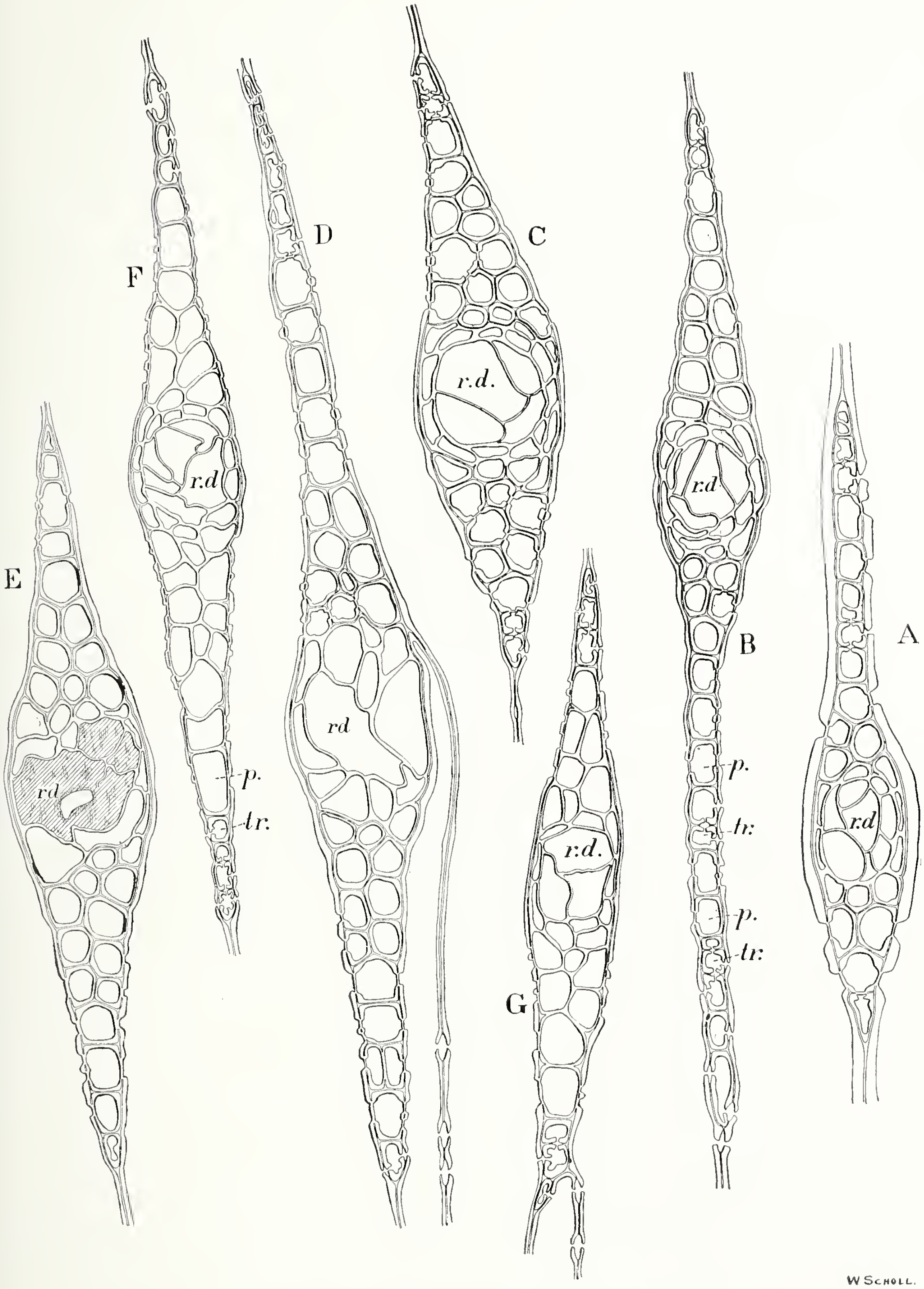
Original magnified $\frac{500}{1}$, illustrations about $\frac{300}{1}$.



TANGENTIAL SECTIONS OF PINUS ECHINATA, HETEROPHYLLA, AND GLABRA, SHOWING NUMBER AND DISTRIBUTION OF PITH RAYS AND PROPORTION OF PITH-RAY CELLS.

A–C and *F*, PINUS HETEROPHYLLA. *D*, PINUS ECHINATA. *E*, PINUS GLABRA.
A–C, Sections of medullary rays; *tr.*, tracheids; *p.*, parenchyma; *C* is a "double" ray.
In *D–F*, histological details are omitted; they are camera drawings showing number and distribution of medullary rays, and also the proportion of the tracheids to parenchyma in each ray, the former being indicated by dots; *r. d.*, transverse resin ducts; *m. r.*, medullary rays.

Magnification of originals: *A–C*, $\frac{500}{1}$; *D–F*, $\frac{85}{1}$; of illustrations: *A–C*, $\frac{300}{1}$; *D–F*, $\frac{85}{1}$.



TRANSVERSE RESIN DUCTS—TANGENTIAL VIEWS.

A-C, PINUS TÆDA. *D* and *E*, P. PALUSTRIS. *F*, P. ECHINATA. *G*, P. HETEROPHYLLA. *r. d.*, resin ducts; *tr.*, transverse tracheids; *p.*, parenchyma.
Magnification of originals, $\frac{500}{1}$; of illustrations, $\frac{300}{1}$.

formed 2 or 3 fibers of normal rings, are thinner, so that in these cases the wood is lighter in color and weight not only because there is relatively less summerwood, but also because the fibers of this summerwood have thinner walls. (See fig. 22, A and B.) In very stunted trees, where the rings are all very narrow, the reduced thickness of the walls is counterbalanced by the smaller size of the cells.

All tracheids communicate with each other by means of the characteristic "bordered" pits, the structure of which is shown in fig. 20. These pits occur only on the radial walls of the fibers. They are most abundant near the ends of each fiber, fewest in the middle, form broken rows, single or occasionally double. (Pl. XXII, C.) As in other pines the pits of the summerwood differ in appearance from those of the springwood. In the latter the pit appears in the cell lumen (radial view) as a perforated saucer-like eminence; in the former as a mere cleft, elongated in the direction of the longer axis of the fiber. (See Pl. XX, B, *d* and *e*; Pl. XXIII, D, *d* and E, *a*.) In both the essential part of the pit is similar, a circular or oval cavity resembling a double convex lens, with a thin membrane dividing it into two equal plano-convex parts. (This membrane is shown only in the drawings, Pl. XXIII, D, and E.) In keeping with the small radial diameter of the fibers of the summerwood, these pits are much smaller in the summerwood than springwood, and usually are very much fewer in number.

The simple pits are in sets and occur only at the points where the fiber touches the cells of a medullary ray. (See fig. 21, also Pl. XXIII, E, sp., and other figures of this plate and Pl. XXIV.) Above and below these simple pits occur very small bordered pits, communicating with those of the short tranverse fibers or tracheids which form part of all medullary rays. (See Pl. XXI, D, *b. p.*)

As in all pines, the medullary or pith rays are of two kinds, the one small, 1 cell wide, and 1 to 10—in large averages 5 to 7—cells high; the other large, and each containing in the middle part a transverse resin duct. (See Pls. XXI, XXIII, XXIV, and XXVI.) Of the former there occur about 21 to 27 on each square millimeter (about 15,000 per square inch) of tangential section. The second class are much less abundant and scattered very irregularly, so that sometimes areas of several square millimeters are found without any of these rays. Generally about one of these rays occurs to every 1.5 or 2 square millimeters, or about 300 to 400 per square inch of tangential section. In all rays the cell rows forming the upper and lower edge (see Pl. XXI) are composed of short fibers or tracheids (transverse tracheids), while the inner rows contain only parenchyma cells. Occasionally small rays occur which are composed of tracheids only. (See Pl. XXI, C.) Frequently the rows of parenchyma are separated by one, rarely by two, series of tracheids (see Pl. XXIII, D, and Pl. XXIV, D), giving rise to "double" or "triple" rays.

The number of cell rows in each medullary or pith ray varies from 2 to 10, on an average from 5 to 7, and of these the rows of tracheids or fibers form more than half. (See Pl. XXV, where the outer cells or tracheids are marked with dots.)

The tracheids of the rays have thick walls covered with point-and-bar-like projections, the boldest of which are on the upper and lower walls and surround the bordered pits. (See Pls. XXI and XXII.) These short tracheids communicate with the common wood fibers, with each other, as well as with the parenchyma cells, by means of small bordered pits, which in this last case are bordered on one side (side of the tracheid) and simple on the other (half-bordered pits). The parenchyma cells occupying the inner rows of each ray communicate in the springwood part of the ring with each neighboring tracheid by 3 to 6, commonly 4 to 5, simple elliptical pits, in the summerwood by a single narrow, elongated slit-like pit (see Pls. XXI and XXII), and with each other by small, irregular, scattered simple pits.

The walls of these cells are generally smooth, but local thickenings, especially on the upper and lower walls, and surrounding the pits, occur quite frequently, though not regularly.

The parenchyma cells of the rays are usually somewhat broader and higher than the fibers, the average height for both being about 21 to 27 μ, the average width about 20 μ, while the length of each cell and fiber, greater in springwood and least in the summerwood, is from two to ten times as great as the height. Assuming 25 μ and 20 μ to represent the average height and width, and allowing 25 rays of 6 cell rows each to each square millimeter of tangential section, then the rays form about 7.5 per cent of the total volume and weight of the wood of these species. An attempt

to utilize for purposes of identification the difference in the number, size, and distribution of these rays, or the proportion between the number of rows of tracheids and those of parenchyma cells, as was done by Dr. J. Schroeder,[1] has not been successful, and appears of little promise.

The large rays with transverse resin ducts resemble the smaller rays described. On Pl. XXIV at A such a ray is seen both in radial and tangential section. Series of transverse tracheids occupy the upper and lower edge, but the interior, unlike that of common rays, is several cells wide, and contains an open duct in its widest portion. (See Pl. XXIV, *r. d.*) This duct is commonly more or less filled with resin (see Pl. XXIV, E); it is surrounded by thin-walled secreting cells, and, in the heart wood, often divided or filled up by thylosis, i. e., by very thin walled, much puffed out cells, growing out of the surrounding secreting cells before the latter perish.

The walls of the secreting cells are quite thin, those of the remainder of the parenchyma vary to some extent in the different species. In the longleaf and loblolly pines the walls of the parenchyma composing the principal part of the ray are generally quite thick (see Pl. XXIV, A–E), thicker than those of the cells of ordinary rays, and especially thickened near the simple pits by which these cells communicate with each other. In Cuban and shortleaf this thickening is much less conspicuous, and absent entirely in many cases (see Pl. XXIV, A), while in the spruce pine it seems wanting altogether.

These ducts exist even in the very first ring (next to the pith), are smaller and more numerous near center, but have essentially the same structure in the wood of the fifth and later years.

The tracheids of the pith rays are wanting next to the pith, but occur in all rays in the outer part of even the first ring. The rays in this ring are generally lower, composed of fewer cell rows, but the cells are larger than the rest of the wood.

Both shape and size of these medullary rays are very variable; an average of about 0.4 mm. for the height of the ray and 60 μ for the width at the resin duct was observed. An attempt to utilize the shape, especially the appearance of the two edges, as a means of separating the wood of these species has so far failed entirely.

The large resin ducts running lengthwise in the wood or parallel to the common wood fibers are much larger than the transverse ducts, measuring, inclusive of the secretive cells, on an average about 0.2 mm. (0.008 inch) on their smaller radial diameter and about 0.3 mm. on the tangential. (See Pl. XX, A, *r. d.*) They are usually situated in the summerwood of each ring, often in narrow rings, causing an irregular outline. They are smaller and more numerous near the pith, here usually forming several series in one annual ring, more numerous in wide rings than in narrow ones, but their number per square inch of cross section as well as their dimensions appear to be independent of the width of the rings. In their structure they resemble those of other pines. They are surrounded by thin-walled resin-secreting parenchyma, part of which often appears as if not directly connected with the duct. (See Pl. XX, A.) In many cases all the tissue between two neighboring ducts is of this parenchyma. Longitudinal and transverse ducts frequently meet and thus form a continuous network of ducts throughout the wood.

ECONOMIC ASPECTS OF FOREST RESOURCES.

One thousand million dollars is the value of the raw products which are annually derived from the forests of the United States.

There is no other resource, there is no other business or trade which approaches in magnitude or importance, in production of values or in the intimate relation to all pursuits of life that which is based upon the exploitation of our forest resources, excepting alone agriculture and its adjuncts.

Professor James, in Bulletin 2 of the Division of Forestry, figured upon the basis of the census for 1880 as follows:

> If to the value of the total output of all our veins of gold, silver, copper, lead, zinc, iron, and coal, were added the value derived from the petroleum wells and stone quarries, and this sum were increased by the estimated value of all the steamboats, sailing vessels, canal boats, flatboats, and barges, plying in American waters and belonging to citizens of the United States, it would still be less than the value of the forest crop by a sum sufficient to purchase at cost of construction all the canals, buy at par all the stock of the telegraph companies, pay their bonded debts, and construct and equip all telephone lines in the United States.

[1] Dr. Julius Schroeder, das Holz der Coniferen, Dresden, 1872.

Even if, instead of the value of the wood article, ready for marketing, we refer only to the stumpage, i. e., the royalty which the wood consumer pays to the land owner for the privilege of taking the valuable material from the land, we will find it ten times as large as the royalties paid for coal, and twenty-five times as large as those paid for iron ore. Nay, even compared with farm rents, the stumpage value of an acre of forest exceeds its farm value.

We can then assert that next to the soil and climate itself, the basis for agricultural production, our forest resources are the most important at the present time as producers of the most needful materials of our civilization. Nay, if we realize that in addition the forest cover as a mere surface condition of the earth affects our local climate, and, still more, acts favorably upon the distribution of our water supplies—the most essential factor in agricultural production—we can not easily overrate its value, either as a factor of production or as an element of protection; its product and its protection are as much necessaries of life as air and water.

It has furthermore this advantage over all other resources, that by the mere manner of exploitation, without much human labor, it can be reproduced; it is a restorable resource which can be utilized without deteriorating or exhausting it, provided the exploitation be carried on rationally and with due regard to the laws of tree growth.

The truth of the assertion that the forest, next to agricultural resources, furnishes a larger product than any other resource, and that the industries relying on wood supplies employ more capital and labor and produce more values in their product than any one other industry or group of like industries, will appear from the following statement:

Leading industries compared.

[Data from Census 1890, in round numbers.]

Articles.	Capital involved.	Employees.	Wages.	Raw material.	Products.
	Millions.	*Thousands.*	*Millions.*	*Millions.*	*Millions.*
Agriculture	$15,982	8,286			$2,460
Forest products, total					1,044
Forest industries, enumerated	562	348	$102	$245	446
Forest products, not enumerated (estimated)	+	+	+		598
Manufactures using wood	543	513	294	412	907
Total wood and wood manufactures					1,951
Mineral products, total					610
Coal	343	300	109		160
Gold and silver	486	57	40		99
Pig-iron industry	134	34	16	110	146
Iron and steel manufactures	414	176	96	327	479
Leather	102	48	25	136	178
Leather manufactures	118	186	88	153	289
Woolen manufactures	297	219	77	203	338
Cotton manufactures	354	222	70	155	268

From this table it appears that agriculture, standing first in capital, persons employed, and value of products, the industries relying upon forest products stand easily second, exceeding in the value of products the mining industries by more than 50 per cent. The industries relying directly or indirectly on forest products employ readily more than one million workers (enumeration being imperfect), producing nearly two billion dollars of value. The manufactures relying on wood wholly or in part more than double the value of the lumber or wood used, giving employment to more than half a million men and about equaling the combined manufactures of all woolen, cotton, and leather goods in persons employed, wages paid, and values produced.

Census statistics of the employment of capital, persons employed, and wages paid in the minor forest industries are absent. The fact that many people are only temporarily or incidentally and for a part of the year engaged in the exploitation of the forest would make such enumeration well-nigh impossible. Besides the lumber industry and such kinds of exploitation as can be, at least, approximately enumerated—always remaining below the truth—a large number of industries and manufactures rely upon wood as the principal material, others employing it to a greater or less extent. An attempt has been made to classify these according to the estimated percentage of wood entering into their products and assuming that capital, labor, and value of products add the same proportion to the total as the raw materials used, and these figures have been employed in the preceding table. As a matter of fact, there is probably more labor employed in shaping wood than this percentage would indicate.

Forest industries and manufactures using wood.

Articles.	Capital.	Employees.	Wages.	Raw material.	Value of product.
Forest industries enumerated:	*Thousands.*	*Hundreds.*	*Thousands.*	*Thousands.*	*Thousands.*
Lumber and mill products	$496, 340	2, 862	$87, 784	$231, 556	$403, 668
Timber products not manufactured at mill	61, 541	461	11, 354	11, 007	34, 290
Naval stores	4, 063	153	2, 933	3, 506	8, 077
Total	561, 943	3, 477	102, 071	245, 169	446, 034
Manufactures practically all wood:					
Cigar boxes	3, 374	55	2, 134	3, 567	7, 092
Packing boxes	13, 018	140	6, 477	14, 245	25, 513
Carriage and wagon stock	13, 028	109	5, 208	1, 388	16, 262
Carpentering	81, 543	1, 409	94, 524	137, 847	281, 195
Cooperage	17, 817	247	11, 655	2, 637	38, 618
Furniture-factory products	66, 394	639	34, 471	38, 796	94, 871
Kindling wood	1, 300	18	772	1, 187	2, 402
Lasts	908	8	572	331	1, 239
Planing-mill products	120, 271	869	48, 970	104, 927	183, 682
Matches	1, 941	18	344	935	2, 194
Wood, turned and carved	7, 826	84	4, 267	3, 947	10, 940
Wooden ware	2, 712	31	1, 237	1, 499	3, 598
Wood pulp	7, 455	28	1, 229	2, 005	4, 628
Wood carpet	333	3	155	214	512
Total	337, 908	3, 650	212, 027	331, 523	672, 750
Manufactures in which wood represents about 50 per cent of the raw materials: *a*					
Total	169, 983	1, 356	714, 460	114, 383	229, 408
Wood percentage	89, 991	687	35, 730	57, 192	114, 704
Manufactures in which wood represents about 33⅓ per cent of the raw materials: *b*					
Total	321, 059	2, 143	123, 588	148, 578	318, 218
Wood percentage	107, 619	714	41, 196	49, 526	106, 072
Manufactures in which wood represents about 10 per cent of the raw materials: *c*					
Total	76, 841	915	46, 854	49, 291	131, 820
Wood percentage	7, 684	92	4, 685	4, 929	13, 182
Total manufactures of wood	543, 402	5, 134	293, 638	443, 170	906, 708

a Includes carriages and wagon-factory product, children's carriages and sleds, steam and street cars, coffins and burial caskets, chairs, wheelbarrows, sewing-machine cases, artificial limbs, refrigerators, and shipbuilding.

b Includes agricultural implements, billiard tables, railroad and street car repairs, furniture repairs, washing machines and wringers, and organs and pianos.

c Includes blacksmithing and wheelwrighting, bridges, brooms and brushes, gunpowder, artists' materials, windmills, toys and games, sporting goods, lead pencils, pipes, and pumps.

The most valuable part of the forest growth, that which it took the longest time to grow, is, of course, that which is cut into lumber. The lumber and sawmill business of the United States has no equal in the world in extent or in efficiency. From being hardly developed fifty years ago beyond local importance, this business, through the development of the means of transportation as well as of the country to the west, has rapidly advanced to enormous proportions.

The extent and distribution of the sawmill business through the States is, perhaps, best illustrated by the following statement of the number of the various classes of mills and their daily capacity as computed from the Directory of the Northwestern Lumberman:

Number of mills, logging railroads, and daily capacity of mills.

[Computed from data published in Northwestern Lumberman, 1892.]

United States.	Sawmills.		Shingle mills. *a*	Staves and heading mills.	Logging railroads.	Daily sawmill capacity.		Daily shingle-mill capacity.	
	Stationary.	Portable.				Lowest.	Highest.	Lowest.	Highest.
						Feet B. M.	*Feet B. M.*	*Number.*	*Number.*
Maine	355	6	292	61	3	4, 686, 000	8, 730, 000	3, 208. 000	6, 275, 000
New Hampshire	270	7	158	40	....	2, 530, 900	4, 720. 000	972, 000	1, 860, 000
Massachusetts	282	20	78	16	1	1, 452, 000	3, 095, 000	390, 000	775, 000
Rhode Island	10	2	6	....	....	48, 000	100, 000	42, 000	75, 000
Connecticut	56	7	22	1	....	342, 000	710, 000	114, 000	215, 000
Vermont	349	20	129	10	1	2, 851, 000	5, 525 000	716, 000	1, 515, 000
New England States	1, 322	62	685	128	5	12, 909, 000	22, 880, 000	5, 442, 000	10, 715, 000
New York	738	42	255	44	10	6, 670, 000	12, 680, 000	2, 266, 000	4, 535, 000
Pennsylvania	887	96	266	39	92	14, 597, 000	27, 190, 000	2, 814, 000	5, 415, 000
New Jersey	73	3	11	....	....	174, 000	540, 000	36, 000	90, 000
Delaware	46	4	2	5	....	252, 000	535, 000	....	5, 000
Maryland	39	6	5	1	2	470, 000	900, 000	12, 000	40, 000
Middle Atlantic States	1, 785	151	539	89	104	22, 163, 000	41, 845, 000	5, 128, 000	10, 085, 000

a Shingles may be averaged 5,000 to the 1,000 feet B. M.

Number of mills, logging railroads, and daily capacity of mills—Continued.

United States.	Sawmills.		Shingle mills.[a]	Staves and heading mills.	Logging railroads.	Daily sawmill capacity.		Daily shingle-mill capacity.	
	Stationary.	Portable.				Lowest.	Highest.	Lowest.	Highest.
						Feet B. M.	*Feet B. M.*	*Number.*	*Number.*
Virginia	100	58	31	8	29	1, 602, 000	3, 260, 000	168, 000	330, 000
North Carolina	140	21	26	2	34	1, 932, 000	3, 605, 000	162, 000	355, 000
South Carolina	70	16	9	2	21	840, 000	1, 580, 000	369, 000	475, 000
Georgia	144	17	57	17	44	3, 086, 000	5, 495, 000	816, 000	1, 470, 000
Southern Atlantic States	454	112	123	29	128	7, 460, 000	13, 940, 000	1, 515, 000	2, 630, 000
Atlantic coast	3, 561	325	1, 347	246	237	42, 532, 000	78, 665, 000	12, 085, 000	23, 430, 000
Florida	123	13	48	4	20	2, 036, 000	3, 665, 000	890, 000	1, 575, 000
Alabama	141	13	20	6	36	2, 514, 000	4, 505, 000	812, 000	1, 655, 000
Mississippi	152	13	18	2	34	2, 740, 000	5, 015, 000	282, 000	505, 000
Louisiana	106	3	29	1	15	1, 926, 000	3, 405, 000	1, 536, 000	2, 945, 000
Gulf States	522	55	115	13	105	9, 216, 000	16, 590, 000	3, 520, 000	6, 680, 000
Texas	150	2	30		61	3, 602, 000	6, 370, 000	890, 000	1, 525, 000
Michigan	847	52	391	101	79	21, 630, 000	42, 045, 000	12, 356, 000	25, 680, 000
Wisconsin	477	32	265	26	20	14, 724, 000	27, 585, 000	8, 706, 000	15, 865, 000
Minnesota	103	2	67	2	2	4, 182, 000	8, 965, 000	2, 700, 000	4, 740, 000
Northern lumbering States	1, 427	86	723	129	101	40, 536, 000	78, 595, 000	23, 762, 000	46, 285, 000
Ohio	576	78	30	82	9	3, 856, 000	7, 820, 000	162, 000	310, 000
Indiana	549	68	32	51		4, 192, 000	8, 130, 000	300, 000	540, 000
Illinois	109	41	9	9	1	1, 158, 000	2, 770, 000	264, 000	445, 000
Northern agricultural States	1, 234	187	71	142	10	9, 206, 000	18, 720, 000	726, 000	1, 295, 000
Lake States	2, 661	273	794	271	111	49, 472, 000	94, 315, 000	24, 488, 000	47, 580, 000
West Virginia	136	93	14	33	40	1, 425, 000	2, 595, 000	770, 000	1, 490, 000
Kentucky	218	117	34	37	10	3, 146, 000	5, 970, 000	306, 000	590, 000
Tennessee	332	111	29	32	20	4, 018, 000	7, 695, 000	180, 000	360, 000
Arkansas	284	33	56	27	45	5, 030, 000	9, 615, 000	1, 074, 000	1, 920, 000
Missouri	184	41	15	9	10	2, 016, 000	3, 820, 000	214, 000	355, 000
Central States	1, 154	395	148	138	125	15, 635, 000	29, 695, 000	2, 544, 000	4, 715, 000
Iowa	42	6	19	2		1, 400, 000	3, 655, 000	900, 000	1, 785, 000
North Dakota	1								
South Dakota	18	1	14			186, 000	360, 000	186, 000	365, 000
Nebraska	4					12, 000	25, 000		
Kansas									
Prairie States	65	7	33	2		1, 598, 000	4, 040, 000	1, 086, 000	2, 150, 000
Interior States	1, 219	402	181	140	125	17, 233, 000	33, 735, 000	3, 630, 000	6, 865, 000
Montana	24	3	11		1	438, 000	1, 000, 000	162, 000	310, 000
Wyoming	10		7			60, 000	110, 000	96, 000	170, 000
Colorado	34	17	29			420, 000	820, 000	318, 000	620, 000
New Mexico	15	1	8		3	222, 000	405, 000	108, 000	210, 000
Indian Territory	17		1			180, 000	250, 000	12, 000	25, 000
Eastern Rocky Mountain region	100	20	56		4	1, 320, 000	2, 685, 000	696, 000	1, 335, 000
Idaho	37	9	20			306, 000	580, 000	150, 000	315, 000
Nevada	6		2		1	212, 000	380, 000	24, 000	50, 000
Utah	31	5	9			182, 000	285, 000	48, 000	95, 000
Arizona	10	1	2		1	146, 000	310, 000	24, 000	50, 000
Western Rocky Mountain region	84	15	33		2	766, 000	1, 555, 000	246, 000	510, 000
Rocky Mountain region	184	35	89		6	2, 086, 000	4, 240, 000	942, 000	1, 885, 000
California	159	3	64	2	33	3, 446, 000	6, 105, 000	2, 202, 000	4, 010, 000
Oregon	184	7	25		11	2, 722, 000	5, 225, 000	380, 000	715, 000
Washington	178	16	83		28	2, 850, 000	5, 500, 000	2, 114, 000	3, 645, 000
Pacific coast	521	26	172	2	72	9, 018, 000	16, 830, 000	4, 696, 000	8, 370, 000
Total	8, 818	1, 118	2, 728	672	717	133, 159, 000	250, 745, 000	40, 251, 000	96, 295, 000

[a] Shingles may be averaged 5,000 to the 1,000 feet B. M.

This sawmill capacity, of between 140,000,000 and 270,000,000 feet B. M. daily, which for our purposes can be considered practically the same to-day, would indicate at the very lowest an annual product of about 35,000,000,000 feet B. M., requiring in round numbers 5,000,000,000 at least cubic feet of forest-grown material.

Besides these mills, such other establishments of woodworking industries as use wood directly from the forest in log or bolt size, like the wood-pulp industry, the cooperage industry, etc., and the requirements of our railroads for ties, bring the total cut surely to 5,500,000,000 cubic feet of wood of superior quality, to furnish which continuously at least 350,000,000 acres must be kept under efficient forest management, as may be figured by inspecting the record of experience in Germany in another part of this report.

This total annual cut, including all material requiring bolt or log size, is estimated at 40,000,000,000 feet B. M. It is made up of the following kinds:

	Feet B. M.
White pine	*12,000,000,000
Spruce and fir	5,000,000,000
Hemlock	4,000,000,000
Longleaf pine	4,000,000,000
Shortleaf and loblolly	3,000,000,000
Cypress	500,000,000
Redwood	500,000,000
All other conifers	1,000,000,000
Total conifers	30,000,000,000
Oak	3,000,000,000
All other hard woods	7,000,000,000
Total	40,000,000,000

In this cut the various regions participate in the following proportions:

	Feet B. M.
New England and North Atlantic States	6,000,000,000
Central States	5,000,000,000
Lake Region	*13,000,000,000
Southern States	13,000,000,000
Pacific States	4,000,000,000
Miscellaneous	2,000,000,000

If we add other materials furnished by the forest supplementing by estimates the data furnished by the census of 1890, we come to the following statement of our total annual wood consumption:

Amount and value of forest products used during the census year 1890.

Classes of products.	Quantity.	Estimated cubic contents of forest-grown material.*a*	Value.
I. Mill products: *b*		*Cubic feet.*	
Agricultural implement stock ... feet, B. M.	30,000,000		$582,000
Bobbin and spool stock ... do	49,000,000		688,000
Carriage and wagon stock ... do	66,000,000		1,306,000
Furniture stock ... do	94,000,000		1,435,000
All other sawed lumber ... do	27,630,000,000		310,818,000
Total sawed lumber ... do	27,869,000,000	4,000,000,000	314,829,000
Laths ... pieces	2,365,000,000		3,709,924
Pickets and palings ... do	110,000,000		750,000
Shingles ... do	9,276,000,000	200,000,000	17,000,000
Staves ... do	1,178,000,000	300,600,000	7,762,000
Headings ... sets	183,000,000	175,000,000	4,934,000
Total lumber and cognate products, directly from logs		4,675,000,000	348,984,924
II. Railroad construction:			
Ties *c* ... pieces	80,000,000	400,000,000	
Round and hewn timber used for bridges and trestles		80,000,000	
Telegraph poles		5,000,000	
Total		485,000,000	40,000,000

a Estimated by the Division of Forestry.

b Theso data have been compilod by Mr. Priest from the reports of 21,011 establishments (representing probably 70 per cent in number and 95 per cent in value of product), of which 18,064 manufactured sawed lumber as principal product, 702 manufactured shingles exclusively, 438 manufactured staves and headings exclusively, and 1,807 used logs or bolts in the manufacture of the various classes of products stated under the head of "Miscollaneous," and corrected by the inclusion of the quantities used for customs sawing not given in the census figures.

c Canvass of Division of Forestry.

* This figure is by this time (1899) greatly reduced on account of the waning supply of White Pine, tho deficiency being made up by increase in other materials, especially Southern pine.

Amount and value of forest products used during the census year 1890—Continued.

Classes of products.	Quantity.	Estimated cubic contents of forest-grown material.*a*	Value.
III. Exported timber not included in Subdivision I: *b*		*Cubic feet.*	
Hewn timber, 6,900,000 cubic feet		9,000,000	$1,230,000
Logs and round timber		2,500,000	2,000,000
Rived staves, stave and bolts		500,000	1,500,000
Total		12,000,000	4,730,000
IV. Wood pulp: *a*			
300,000 tons ground paper pulp			
80,000 tons soda pulp			
60,000 tons sulphite pulp fiber		75,000,000	3,550,000
50,000 tons pulp for other purposes			
V. Miscellaneous mill products other than lumber manufactured directly from logs or bolts *e*		80,000,000	20,765,000
Total materials requiring bolt or log size		5,327,000,000	418,029,924
This last figure of "miscellaneous products" is a very considerable underestimate, based upon census returns, and we are entirely safe in rounding off the total of sizable timber used and its value to		5,500,000,000	450,000,000
VI. Fuel in the shape of wood *d*		18,000,000,000	450,000,000
In the shape of charcoal		250,000,000	7,000,000
VII. Wood used for dyeing extracts and charcoal for gunpowder *e*		16,200,000	437,000
Total amount and value of wood consumption		23,766,000,000	907,437,000
		Value.	Total value.
VIII. Naval stores: *c*			
Turpentine ... barrels	346,544	$5,459,115	
Rosin ... do	1,429,154	2,413,757	$7,872,872
IX.*e* Wood alcohol ... gallons	2,000,000	1,750,000	
Acetic acid in acetate of lime		360,000	2,110,000
X. Tanning materials: *c*			
Hemlock bark ... cords	1,056,000	6,925,000	
Oak bark ... do	322,150	2,783,500	
Hemlock and bark for extract ... do	64,200	307,500	
Sumac leaves for tanning ... tons	3,300	198,000	
Sumac leaves for extract ... do	3,750	112,000	
Various, not accounted for		74,000	10,400,000
XI. Maple sugar ... pounds *e*	32,952,927	3,300,000	
Maple sirup ... gallons *e*	2,258,376	2,200,000	5,500,000
Total value of forest by-products			25,882,872
Total value of all forest products			933,319,872
Add 10 per cent for omissions and underestimates *a*			93,331,987
Total value of wood and forest products at original place of production, estimated to have been used during census year 1890			1,026,650,859

a Estimated by the Division of Forestry.
b From returns of Bureau of Statistics, U. S. Treasury Department.
c Based on figures of the Eleventh Census.
d Based on figures of the Tenth Census and canvass of Division of Forestry.

Making allowance for the increase in business and values and rounding off the values given for 1890, we may estimate the present conditions about as follows:

Mill products, lumber, shingles, implement and furniture stock, etc	$450,000,000
Railroad construction	45,000,000
Export timber	5,000,000
Wood pulp	5,000,000
Miscellaneous bolt sizes	50,000,000
Total materials requiring log and bolt sizes	555,000,000
Fuel and fencing	450,000,000
Charcoal	7,000,000
Dyewood and gunpowder	500,000
Naval stores	8,500,000
Wood alcohol and acetic acid	2,500,000
Tanning material	15,000,000
Maple sirup and sugar	5,500,000
Grand total	1,044,000,000

It should, of course, be understood that all such figures are mere approximations to the truth based upon careful consideration of the partial information obtainable for the single items.

In comparison with these enormous amounts and values expressing home consumption and home production, the amounts of imports and exports become quite insignificant.

The imports of wood and other forest materials amount to between twenty and thirty million

dollars annually, about 25 per cent of which consists of materials which do not grow on this continent. The balance comes mainly from Canada.

The exports of forest products and partly manufactured wood materials varied until two years ago between twenty-five and thirty million dollars, with twelve to fifteen million more of manufactures in which wood plays an important part.

To be sure, there are constant increases in exports as well as imports, but the amounts as stated are small in comparison, with home production and consumption remaining generally below the thirty-million-dollar mark, and a little above or below 3 per cent of all exports, as appears from the following table, which shows the value of exports of forest products, crude, or only slightly enhanced in value by manufacture:

Value of exports of forest products, 1860-1897.

Year.	Value.	Total exports of domestic products.	Year.	Value.	Total exports of domestic products.	Year.	Value.	Total exports of domestic products.
		Per cent.			*Per cent.*			*Per cent.*
1860	$10, 299, 959	3. 26	1882	$25, 580, 264	3. 50	1891	$28, 715, 713	3. 29
1870	14, 897, 963	3. 27	1883	28, 636, 199	3. 56	1892	27, 957, 423	2. 75
1875	19, 165, 907	3. 43	1884	26, 222, 959	3. 62	1893	28, 127, 113	3. 38
1876	18, 076, 668	3. 04	1885	22, 014, 839	3. 03	1894	28, 000, 629	3. 22
1877	19, 943, 290	3. 14	1886	20, 961, 708	3. 15	1895	28, 576, 235	3. 61
1878	17, 750, 396	2. 55	1887	21, 126, 273	3. 01	1896	33, 718, 204	3. 91
1879	16, 336, 943	2. 34	1888	23, 991, 092	3. 51	1897	40, 489, 321	3. 92
1880	17, 321, 268	2. 11	1889	26, 997, 127	3. 70			
1881	19, 486, 051	2. 20	1890	29, 473, 084	3. 49			

To get an idea of the character of the materials exported, whether raw or manufactured, and the approximate territorial distribution of the same, the following table is reproduced from the report of the Division of Forestry for 1892. It shows that the Southern States furnish the largest amount of raw material exports in value, while the Northern States furnish the bulk of the manufactured articles. To be sure, for this tabulation only the freights at ports could be utilized which do not allow a very close territorial distribution of the place of production.

Exports of wood and certain wood products during the year ending June 30, 1892, by districts of country whence exported.

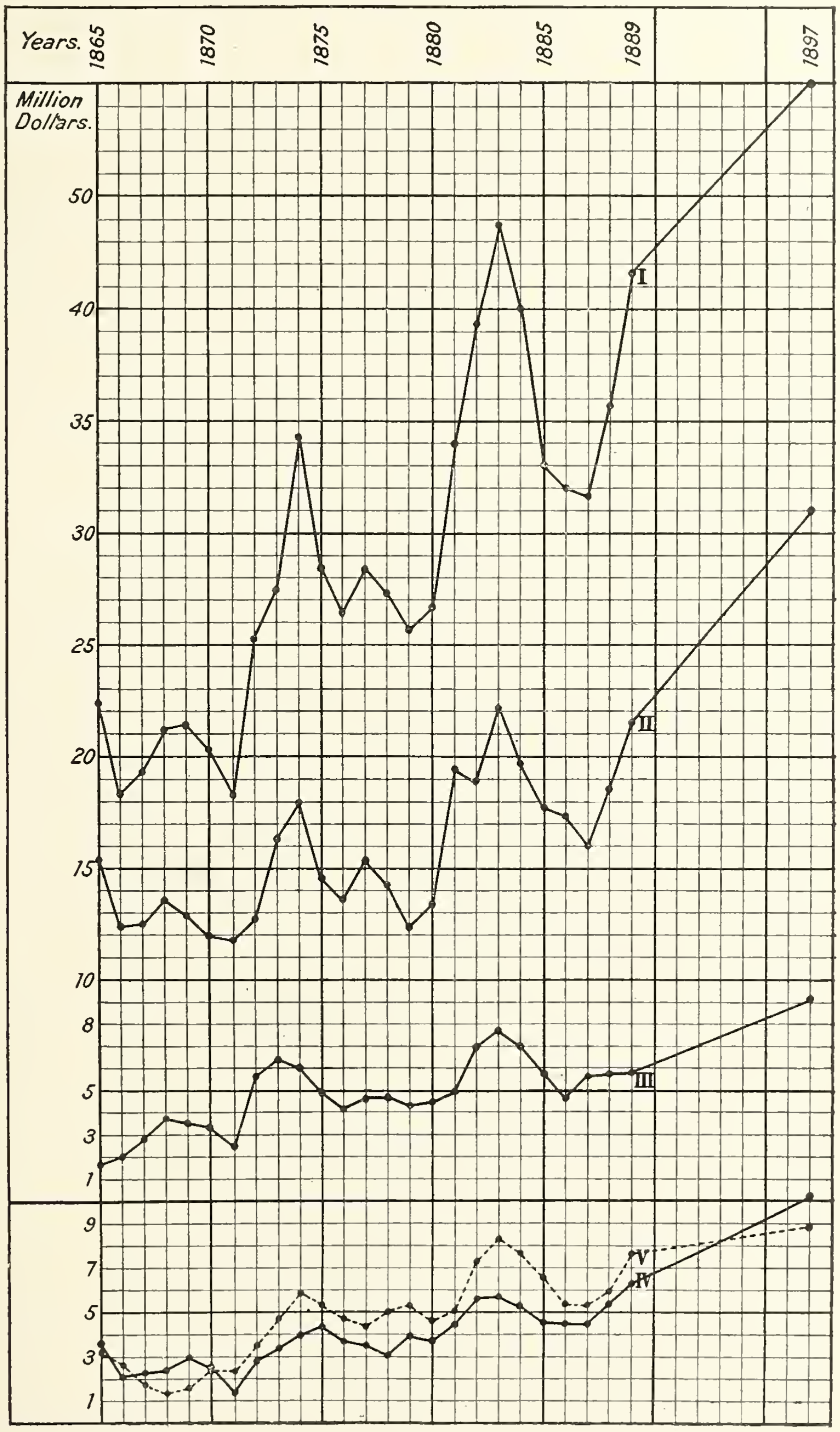
Products.	Districts.*a*				
	No. 1.	No. 2.	No. 3.	No. 4.	Total.
Raw materials:	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Boards, deals, planks, etc	3, 089, 115	2, 220, 327	2, 962, 732	1, 400, 319	9, 672, 493
Joists and scantling	16, 953	157, 136	43, 739	10, 685	228, 513
Hoops and hoop poles	74, 626	13, 465		131	88, 222
Laths	2, 337	75	620	14, 685	17, 717
Palings and pickets	76	1, 183	293	4, 707	6, 259
Shingles	5, 841	39, 671	13, 171	29, 309	87, 992
Shooks	691, 867	46, 052	1, 899	41, 719	781, 537
Staves	946, 210	709, 952	551, 578	3, 976	2, 211, 716
All other lumber	657, 304	29, 651	250, 687	113, 755	1, 051, 397
Timber (sawed)	37, 235	259, 653	1, 844, 333	531, 933	2, 673, 154
Timber (hewn)	242, 770	57, 986	682, 818		983, 574
Logs and other round timber	875, 371	740, 502	268, 985	38, 746	1, 923, 604
Firewood	1, 604				1, 604
Rosin	652, 777	2, 755, 811	8, 123	1, 748	3, 418, 459
Tar	38, 534	12, 078	226	1, 679	52, 417
Turpentine and pitch	15, 965	2, 217	38	116	18, 336
Spirits of turpentine	445, 249	4, 050, 533	429	4, 510	4, 500, 721
Bark and bark extract	84, 268	155, 440			239, 708
Total raw materials	7, 878, 102	11, 251, 732	6, 621, 671	2, 198, 018	27, 957, 423
Manufactures:					
Agricultural implements	3, 682, 784	19, 042	65, 753	27, 404	3, 794, 983
Carriages and horse cars	1, 799, 344	550	73, 954	70, 322	1, 944, 170
Cars, passenger and freight	1, 145, 473	95, 419	56, 565	22, 808	1, 320, 265
Matches	48, 657	76	3, 395	21, 537	73, 666
Organs	748, 938	19, 970	1, 573	2, 101	772, 582
Doors, sash, and blinds	191, 045	633	12, 124	92, 116	295, 918
Moldings, trimmings, etc	169, 623	14, 592	1, 423	16, 951	202, 589
Hogsheads and barrels, empty	281, 533	326	5, 162	3, 092	290, 113
Household furniture	2, 751, 111	48, 114	112, 261	178, 660	3, 090, 146
Wooden ware	326, 991	27, 197	2, 289	76	356, 553
All other wood manufactures	1, 551, 013	134, 626	54, 647	87, 182	1, 827, 470
Total manufactures	12, 696, 514	360, 545	389, 146	522, 249	13, 968, 455
Total exports	20, 569, 217	11, 612, 277	7, 010, 817	2, 720, 267	41, 925, 878

a District No. 1 includes all of the United States north of Baltimore and east of the Rocky Mountains. District No. 2 includes the territory having its outlet by the South Atlantic ports. District No. 3 includes the territory adjacent to the Gulf ports. District No. 4 embraces that portion of the United States bordering on the Pacific Ocean.

The following diagram shows graphically the changes in export during the last thirty-two years:

Range of exports of forest products for twenty-five years from 1865 to 1889, and 1897.

I. All forest products, crude and manufactured.
II. Lumber, timber, and partly manufactured wood products.



III. Naval stores.
IV. Wood manufactures, wholly of wood.
V. Manufactures partly of wood.

NOTE.—The above summary of exports, in addition to the materials given in the summary of the Bureau of Statistics as "Wood and its manufactures," properly includes the following products, being entirely or in their

material largely derived from the forest: Naval stores, bark and tanning extracts, ashes, ginseng, sumac, together with matches, agricultural implements, carriages, cars, and musical instruments.

During the last two years a notable increase in exports has taken place, which brings the figures for wood products and wood manufactures, with nearly $60,000,000, to more than double the amount of ten years ago, and 40 per cent more than five years ago, when the exports amounted to nearly $43,000,000. This increase unfortunately is mostly in raw materials, logs, and lumber, and is probably due to a very active export trade, especially in oak, with Germany. The naval store industry has also considerably increased in exports.

To show how the various articles of export compare the following table will serve, in which the exports of 1890 and 1897 are recorded:

Exports of wood and wood products from the United States for the years ending June 30, 1890 and 1897.

Products.	1890.		1897.	
	Quantity.	Value.	Quantity.	Value.
Agricultural implements:				
Horsepowers		$3,474		
Mowers and reapers		2,092,638		$3,127,415
Plows and cultivators		878,874		590,779
All other, and parts of		884,238		1,522,492
Bark, and extract of, for tanning		263,754		241,979
Carriages and horse cars		2,056,980		1,955,760
Cars for steam railroads ... number	3,662	2,689,698		990,950
Ginseng ... pounds	223,113	605,233	179,573	840,686
Organs ... number	11,490	750,583	13,725	799,132
Matches		62,284		70,988
Rosin ... barrels	1,601,377	2,762,373	2,429,116	4,688,163
Tar ... do	28,806	56,105	17,640	34,878
Turpentine and pitch ... do	18,327	35,037	18,920	44,366
Spirits of turpentine ... gallons	11,248,920	4,590,931	17,302,823	4,447,551
Firewood ... cords	7,648	16,746		(a)
Boards, deals, and planks ... M feet	612,814	9,974,888	876,689	13,076,247
Joists and scantling ... do	26,684	381,640	36,253	423,875
Hoops and hoop poles		59,978		(a)
Laths ... M	10,491	24,951		(a)
Palings, pickets, and bed slats ... M	2,981	30,653		(a)
Shingles ... M	36,527	111,926	58,508	103,231
Shooks:				
Box		118,557		529,492
Other ... number	534,190	766,607	698,858	597,606
Staves and headings		2,476,857		3,922,931
All other lumber		1,355,141		3,162,470
Timber:				
Sawed ... M feet	270,984	3,384,847	391,291	4,036,214
Hewn ... cubic feet	8,732,761	1,381,747	6,406,824	1,236,112
Logs and other round timber		1,680,346		3,945,106
Doors, sash, and blinds		320,840		857,401
Moldings, trimmings, and other house finishings		116,295		197,934
Hogsheads and barrels, empty		425,278		267,345
Household furniture		3,088,902		3,785,143
Wooden ware		360,515		531,480
All other wood manufactures		2,197,815		3,253,110
Total		46,006,781		59,329,936

a Not specified.

While undoubtedly increase in prices influences somewhat these figures, the following diagram, showing the range of prices for export materials, would indicate that this influence has not been appreciable, the prices remaining remarkably even, with the exception of the period after the war, and lately showing even a sinking tendency, although probably only temporarily.

Annual average export prices of wood and certain wood products for each of the ten years ending June 30 from 1882 to 1891, and 1897.

Articles.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1897.
Wood, and manufactures of:											
Boards, deals, and planks ... M feet	$16.90	$16.78	$17.06	$15.93	$15.20	$15.38	$16.39	$16.99	$16.28	$16.17	$14.90
Joists and scantling ... do			15.44	14.06	13.97	14.67	15.16	13.37	14.30	13.70	11.70
Laths, palings, pickets, bed slats, etc ... M			2.43	2.13	2.71	2.39	2.57	2.44	2.38	2.61	
Shingles ... M	3.07	3.04	2.96	2.90	2.45	2.63	3.07	2.89	3.06	2.75	1.76
Firewood ... cord	3.99	3.60	3.58	3.20	3.15	3.10	3.32	2.72	2.27	3.41	
Timber, sawed ... M feet			11.17	10.50	10.82	11.79	12.41	12.38	12.49	11.88	10.30
Timber, hewn ... cubic feet			.16	.15	.16	.16	.17	.18	.16	.18	.19
Naval stores:											
Rosin ... barrels			1.83	1.73	1.74	1.69	1.53	1.49	1.72	1.94	1.96
Tar ... do			2.10	1.77	1.90	1.94	1.96	1.90	1.95	2.26	1.98
Turpentine and pitch ... do			2.23	1.85	2.48	2.08	1.74	1.81	1.91	2.01	2.35
Spirits of turpentine ... gallons	.47	.44	.34	.30	.34	.34	.34	.39	.41	.38	.25

We find also by inspection of trade journals that, although many of the great staples have in some regions been entirely exhausted and in others approach exhaustion, prices of lumber have not

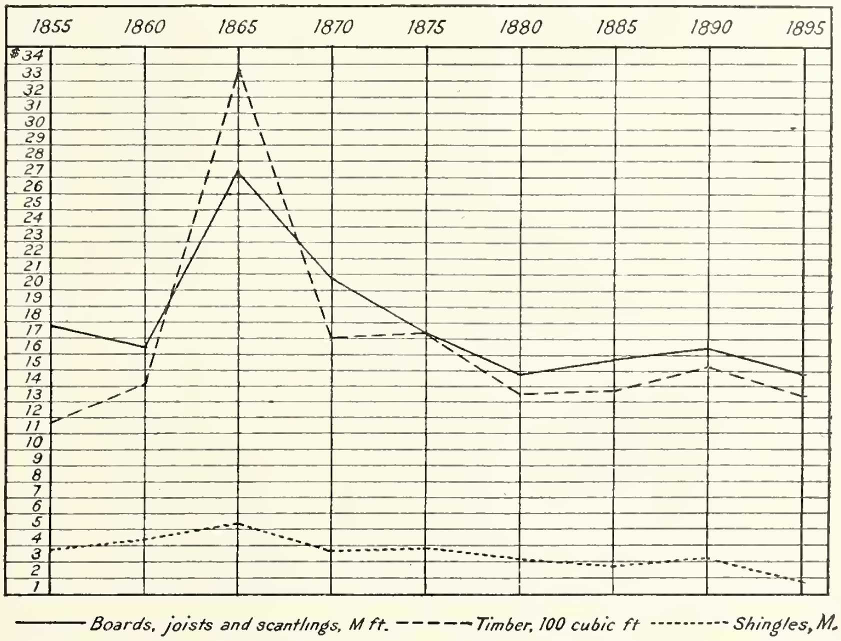
advanced in proportion for various reasons. Competition, stimulated by active railroad building, opening up of virgin fields of supply, improved machinery, systematized methods of logging and of handling and marketing material have tended to keep the price down.

Meanwhile stumpage has increased rapidly for such kinds as show rapid decrease in supply. Thus white pine stumpage more than doubled in ten years, while walnut, tulip poplar, and ash stumpage has increased manyfold as the supply has grown scarcer.

In the markets, while the average price for lumber has advanced but little, the better grades have appreciated disproportionately. From the carefully collected census statistics for ship-

Export price of lumber from 1855 to 1895.

[The prices given represent market value at time of exportation in the ports whence the lumber was exported, averaged for all ports.]



building, which requires all first-class material, the average price per 1,000 feet, B. M., for the country at large for the following kinds appears:

Kind.	Average.	Lowest.	Highest.
White oak	$30.70	$19.00 (Indiana)	$125.00 (California).
Other oaks	34.90	20.00 (Indiana, Kentucky, West Virginia)	102.00 (California).
Hard pine	24.40	12.00 (Alabama)	42.00 (Iowa).
White pine	34.70	20.00 (Minnesota)	100.00 (Georgia).
Fir	21.00	15.00 (Washington)	80.00 (Massachusetts).
Spruce	20.00	12.00 (Delaware)	50.00 (Washington).
Cedar	40.00	17.00 (Missouri)	55.00 (Connecticut).
Cypress	31.60	18.00 (Mississippi)	50.00 (Delaware).
Average of all	30.00		

Firewood, even in the densely settled parts, remains stationary in price, on account of abandoned farms and culled woodlands producing it in abundance; in fact, in many sections its value has decreased, competition of coal aiding in its reduction.

Prices for lumber and stumpage of white pine.

[Compiled from report of Saginaw Board of Trade.]

Year.	Lumber, per 1,000 feet B. M.	Stumpage, per 1,000 feet.	Year.	Lumber, per 1,000 feet B. M.	Stumpage, per 1,000 feet.
1866	$11.50 to $12.00	$1.00 to $1.25	1877	$9.25 to $9.75	$2.25 to $2.75
1867	12.00 12.50	1.25 1.50	1878	9.50 10.00	2.25 2.75
1868	12.00 12.50	1.50 1.75	1879	10.50 11.00	2.50 2.75
1869	12.50 13.00	2.00 2.50	1880	11.50 12.00	2.75 3.00
1870	12.00 12.50	2.00 2.50	1881	12.50 13.00	3.00 4.00
1871	12.50 13.00	2.00 2.50	1882	14.00 14.50	3.50 4.50
1872	13.00 12.00	2.00 2.50	1883	13.50 14.00	4.00 5.00
1873	11.50 11.00	2.00 2.50	1884	12.50 13.00	4.00 5.00
1874	10.50 10.00	2.00 2.50	1885	12.50 13.00	4.50 6.50
1875	9.50 10.00	2.25 2.75	1886	12.50 13.00	4.50 6.50
1876	9.00 9.50	2.25 2.75	1887	12.50 13.00	4.50 6.50

To show what position we occupy as exporters of forest products the following tabulations reproduced from the report of the Division of Forestry for 1887 will be of interest, placing the United States fourth among the seven or eight great exporters, the general position having hardly changed to date. Austria-Hungary should have been included in this comparison; it would not, however, materially change the relations.

Review of the timber export trade of the principal exporting countries. (*a*)

Countries.	1885.	1886.	1887.
	Cubic feet.	*Cubic feet.*	*Cubic feet.*
Sweden	119, 588, 040	113, 805, 285	121, 966, 020
Norway	67, 600, 500	64, 812, 000	65, 455, 500
Finland	46, 246, 860	39, 480, 725	42, 095, 625
Russia (imperfect)	148, 691, 400	146, 352, 340	149, 609, 955
Germany (official)	62, 927, 700	54, 287, 000	63, 153, 100
Italy (oak staves)	507, 390	357, 400	717, 850
Canada (official)	159, 658, 880	172, 910, 890	168, 028, 850
United States (official)	127, 372, 930	122, 173, 650	114, 074, 370
Total	732, 593, 700	714, 179, 280	744, 901, 270

Amount and prices of hewn and sawn wood (exclusive of staves and furniture wood) imported into Great Britain, and proportion furnished by various countries. (*a*)

Year.	Amount.	Price per 100 cubic feet.	Approximate percentages.					
			Norway, Sweden.	Russia.	Canada.	Germany.	United States.	Other countries.
	Cubic feet.							
1881	276, 757, 300	$2.72	36	20	23	4	7	9
1882	309, 758, 350	2.54	36	24	21	5	6	8
1883	322, 811, 900	2.42	36	20	26	5	6	7
1884	299, 863, 750	2.26	37	22	20	5	7	9
1885	308, 248, 950	2.25	37	23	20	5	6	9
1886	268, 059, 960	2.11	38	23	21	3	7	8
1887	275, 451, 000	(?)	38.7	23.7	19	3.6	7	8
Average	294, 421, 600	2.38	36.8	22.3	21.5	4.4	6.7	8.3

a These two tables have been compiled partly from reports given by the Timber Trade Journal, of London, England, and partly from other sources.

As to imports, the changes from year to year are also comparatively trifling, though, of course, in the direction of increase, remaining also for the last ten years below $30,000,000 and ranging within $10,000,000 to $14,000,000.

In these imports about one-fifth represents materials which we do not or can not produce in our country—such as certain cabinet woods, mahogany, ebony, etc., cork, and certain dye and tanning materials. The other four-fifths is material which comes into competition with our own products, and the bulk of this comes from Canada. Yet, balancing our imports with exports from and to that country, we do not get more than about $10,000,000 worth from our neighbor, an insignificant percentage of the one-billion dollar annual home product. This will appear from the following tables:

Value of imports of wood and wood manufactures from Canada to the United States.

[United States Bureau of Statistics.]

From—	1892.	1893.	1894.	1895.	1896.
Nova Scotia and New Brunswick:					
Free	$413, 536	$340, 680	$334, 267	$1, 972, 885	$2, 762, 630
Dutiable	742, 875	888, 789	658, 806	179, 489	85, 056
Quebec and Ontario:					
Free	1, 640, 804	2, 642, 094	3, 415, 403	9, 240, 665	11, 700, 851
Dutiable	9, 012, 215	9, 974, 274	7, 735, 856	950, 778	19, 969
British Columbia				108, 179	133, 148
Total	11, 809, 430	13, 845, 837	12, 144, 332	12, 451, 996	14, 701, 694

Value of exports of wood and wood manufactures from the United States to Canada.

[United States Bureau of Statistics.]

To—	1892.	1893.	1894.	1895.	1896.
Nova Scotia and New Brunswick	$115, 110	$92, 208	$208, 737	$190, 196	$216, 977
Quebec and Ontario	1, 746, 867	1, 990, 831	2, 740, 868	2, 416, 728	2, 723, 459
British Columbia	100, 743	100, 012	111, 914	146, 423	152, 079
Total	1, 962, 720	2. 183, 051	3, 061, 519	2, 753, 347	3, 092, 515

The character and relative proportion of the imports will appear from the following tabulation, in which the segregation of articles free of duty and dutiable refers to conditions prevailing in 1892 and 1893; while in 1897 the bulk of lumber and timber was on the free list. Adding dyewoods and their extracts, sumac and other tanning materials, and such smaller wood products as form an inconspicuous part in manufactures, the amount of imports would be increased by about $1,500,000.

Imports of wood and wood products for home consumption during the years ending June 30, 1892, 1893, and 1897.

Articles.	1892.		1893.		1897.
	Quantity.	Value.	Quantity.	Value.	Value.
Free of duty.					
Firewood ... cords	198, 850	$411, 482	199, 187	$403, 601	$252, 352
Logs and round timber		1, 188, 797		2, 164, 273	2, 616, 397
Railroad ties ... number	748, 520	131, 295	619, 235	97, 857	244, 817
Shingle and stave bolts		44, 387		53, 505	(a)
Handle and head bolts		59, 573		53, 129	39, 924
Ship timber		31, 721		29, 865	(a)
Ship planking		79, 622		8, 404	342, 320
Hop poles		18, 412		38, 968	(a)
Wood for pulp making		230, 959		332, 244	651, 897
Charcoal		48, 395		51, 634	(a)
Cabinet woods—cedar, ebony, mahogany, etc		2, 234, 003		2, 662, 658	1, 273, 101
Cork bark		1, 368, 244		1, 641, 294	1, 323, 409
Hemlock bark ... cords	53, 018	256, 346	50, 699	241, 244	133, 051
Bamboos, rattans, canes, etc		1, 198, 813		922, 529	806, 703
Briar root or briar wood, and the like, partially manufactured		39, 185		40, 470	54, 342
Ashes		54, 855		76, 306	(a)
Fence posts		31, 351		31, 051	(a)
Tar and pitch of wood ... barrels	768	3, 352	1, 179	6, 376	262, 928
Turpentine, spirits of ... gallons	9, 337	3, 470	10, 273	4, 077	1, 936
Turpentine, Venice ... pounds	36, 642	3, 992	20, 694	2, 365	3, 013
Pitch, Burgundy ... do	281, 430	4, 386	207, 220	3, 558	3, 248
Total free		7, 442, 640		8, 865, 408	7, 309, 438
Dutiable.					
Wood unmanufactured not specially provided for		32, 655		25, 952	(a)
Timber:					
Used for spars, wharves, etc ... cubic feet	12, 295	2, 301	9, 432	943	(a)
Hewn and sawed ... do	445, 804	54, 570	1, 419, 484	62, 868	251, 624
Squared or sided not specially provided for ... do	14, 036	1, 392	65, 139	492	(a)
Lumber:					
Boards, planks, deals, and other sawed lumber ... M feet	482, 339	5, 588, 948	529, 263	6, 283, 805	9, 075, 981
Sawed lumber, not otherwise specified ... do	150, 184	1, 416, 331	162, 955	1, 533, 274	(a)
Sawed boards, planks, deals—cedar, ebony, etc	222	5, 117	366	24, 205	(a)
Clapboards ... M	6, 259	99, 187	7, 072	113, 988	(a)
Hubs, posts, laths, and other rough blocks		29, 823		28, 227	4, 721, 000
Laths ... M	259, 157	327, 359	327, 442	462, 140	469, 563
Pickets and palings ... M	3, 157	22, 679	5, 483	36, 700	27, 024
Cedar poles, posts, and railroad ties ... No	2, 115, 986	259, 583	1, 815, 949	271, 236	172, 812
Shingles ... M	362, 551	731, 299	470, 001	916, 759	1, 296, 502
Shooks		62, 981		45, 746	(a)
Staves		551, 557		646, 613	632, 584
Manufactures, all others:					
Barrels or boxes containing oranges, lemons, etc., apart from contents		467, 514		555, 987	609, 700
Casks and barrels, empty		919		531	(a)
Chair cane or reeds manufactured		181, 337		173, 967	205, 242
Cabinetware and household furniture		411, 712		382, 199	272, 166
Osier or willow, prepared for manufacture		82, 633		64, 427	13, 047
Osier or willow, manufactures of		123, 820		125, 916	100, 672
Wood pulp ... tons	41, 141	1, 831, 231	63, 633	2, 909, 097	800, 886
Veneers of wood		8, 264		750	(a)
Bark extract, for tanning ... pounds	12, 973	408	672	71	(a)
Sumac ... do	12, 724, 703	294, 744	7, 244, 132	398, 400	(a)
Corks and cork bark manufactured ... do	671, 064	321, 480	703, 063	351, 731	461, 413
Matches		83, 157		133, 152	207, 671
Frames and sticks for umbrellas		b 92, 437		b 117, 258	(a)
All other manufactures of wood or of which wood is the component of chief value		1, 277, 644		1, 397, 155	1, 769, 624
Total dutiable		14, 364, 100		17, 163, 589	21, 087, 311
Total imports		21, 806, 740		26, 028, 997	28, 396, 749

a Not specified, included in other items.

b Including other materials.

In former years the imports were more closely differentiated in the reports of the Statistical Bureau, especially as to the kinds of cabinet woods. To show this differentiation, and also to enable us to form an idea of the amount of wood represented in the importations of materials which we could produce, and in our exports, an estimate of their cubic contents was made in the report of the Division of Forestry for 1887. A portion of the tables, which covered the period from 1880 to 1887, is here reproduced. It appears from these that our imports represent in the neighborhood of 100,000,000 cubic feet of wood, while our exports, worth nearly $60,000,000, must at present amount to probably 200,000,000 cubic feet. From these tabulations we also see that we pay for imports at the rate of 15 to 16 cents per cubic foot, while our exports are figured at between 11 and 12 cents.

Exports of wood and wood products, 1883–1887.

Articles.	1883.		1884.		1885.		1886.		1887.	
	Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.
Firewood	432, 600	$15, 552	254, 016	$9, 464	209, 376	$6, 985	261, 408	$8, 568	160, 600	$4, 975
Boards, deals, and planks	41, 617, 166	8. 377, 908	34, 438, 360	7, 079, 701	34, 231, 192	6, 570, 576	36, 155, 464	6, 620, 911	35, 396, 666	6, 531, 144
Joists and scantling			1, 048, 456	195, 043	1, 081, 324	183, 166	898, 143	151, 119	717, 250	126, 284
Hoops and hooppoles, etc	1, 737, 300	138, 983	4, 455, 900	356, 470	4, 332, 450	346, 598	2, 804, 850	224, 385	2, 673, 150	213, 852
Laths			153, 000	22, 295	158, 617	20, 277	295, 855	48, 377	221, 008	32, 940
Palings, pickets, and bedslats	a 301, 100	45, 168	114, 540	15, 615	174, 881	28, 515	150, 645	10, 544	109, 680	13, 853
Shingles	938, 826	203, 779	857, 141	183, 521	637, 042	132, 976	581, 996	103, 049	541, 016	101, 282
Shooks, box	357, 332	89, 333	653, 985	186, 853	720, 426	205, 836	604, 498	174, 723	547, 016	136, 754
Shooks, other	a 48, 674, 010	4, 867, 401	4, 579, 311	1, 526, 437	4, 396, 395	1, 465, 465	3, 295, 041	1, 198, 444	2, 815, 515	938, 505
Staves and headings			40, 297, 200	2, 686, 473	29, 261, 100	1, 950, 794	30, 451, 500	2, 030, 097	30, 089, 325	2, 005, 955
All other lumber	13, 063, 660	1, 567, 631	8, 135, 000	976, 191	9, 841, 200	1, 182, 142	9, 792, 500	1, 175, 099	10, 036, 600	1, 204, 392
Timber, sawed	19, 913, 220	3, 102, 232	16, 704, 331	2, 247, 328	12, 770, 667	1, 609, 485	16. 112, 000	2, 092, 557	13, 967, 410	1, 976, 750
Timber, hewed			10, 615, 065	1, 735, 382	8, 411, 066	1, 289, 281	5, 037, 612	829, 019	4, 260, 639	697, 915
Logs and other timber	31, 757, 962	1, 540, 637	21, 307, 900	1, 704, 635	21, 147, 200	1, 691, 780	15, 732, 100	1, 258, 575	13, 015, 975	1, 041, 278
Total unmanufactured	158. 793, 116	20, 948. 624	143, 614. 205	18, 925, 408	127, 372, 936	16, 683, 878	122, 173, 652	15, 934, 467	114, 551, 850	15, 065, 879
Manufactures of—										
Doors, sash, and blinds	....	....	393, 256	294, 942	378, 688	284, 016	356, 007	267, 005	364, 437	273, 328
Moldings, trimmings, etc	....	....	231, 548	173, 661	175, 204	131, 403	139, 913	104, 935	152, 080	114, 061
Hogsheads and barrels, empty	401, 645	301, 234	426, 912	320, 184	432, 275	324, 206	663, 277	497, 458	609, 333	456, 992
Household furniture	3, 439, 158	2, 579, 369	3, 239, 775	2, 429, 831	2, 838, 256	2, 128, 692	2, 829, 083	2, 121, 812	2, 638, 327	1, 978, 745
Woodenware	689, 072	516, 770	541, 685	406, 264	428, 619	321, 464	441, 647	331, 235	434, 648	325, 986
All other manufactures	3, 263, 615	2, 447, 711	2, 290, 784	1, 724, 838	2, 120, 952	1, 590, 714	1, 848, 531	1, 386, 398	1, 973, 257	1, 479, 943
Total manufactures	7, 793, 445	5, 845, 084	7, 132, 960	5, 349, 720	6, 373, 994	4, 780, 495	6. 278, 458	4, 708, 843	6, 172, 082	4. 629, 055
Naval stores:										
Rosin				2, 909, 074	....	2, 198, 267	....	1, 963, 091	....	2, 301, 636
Tar	....	3, 242, 818	....	91, 248	....	66, 449	....	36, 208	....	39, 772
Turpentine and pitch				118, 842	....	29, 847	....	32, 999	....	29, 270
Spirits of turpentine	....	4, 366, 229	....	3, 885, 500	....	2, 690, 231	....	2, 811, 777	....	3, 489, 985
Total naval stores and spirits of turpentine	....	7, 609, 047	....	7, 004. 700	....	4, 984, 794	....	4, 844, 075	....	5, 860, 663
Bark and tanning extracts	....	87, 528	....	292, 851	....	346, 218	....	283, 086	....	239, 700
Matches	41, 499	124, 499	35, 603	106, 809	23, 280	69, 840	27, 401	82, 204	25, 793	77, 379
Agricultural implements	....	3, 883, 919	....	3, 442, 767	....	2, 561, 602	....	2. 367, 258	....	2, 138. 398
Sewing machines	122, 466	3, 061, 639	142, 112	3, 552, 814	115, 944	2, 898, 698	103, 388	2, 584, 717	....	....
Musical instruments	....	1, 20[illegible], 612	....	1, 079, 118	....	941, 344	....	871, 446	....	831, 837
Miscellaneous	163, 965	8, 361, 197	177, 715	8, 474, 359	139, 224	6, 817, 702	130, 789	6, 188, 724	25, 793	3. 287, 314
Total	166, 750, 526	42, 763, 952	150, 924, 880	39, 754, 187	133, 886, 154	33, 266, 869	128, 582, 899	31, 676, 109	120, 749, 725	28, 842, 881

a The estimates of cubic feet marked (a) are based upon the values given and not upon official reports of quantity, and are therefore to be taken as only approximately correct.

Imports of wood and wood products, 1883–1887.

Articles.	1883. Cubic feet.	1883. Value.	1884. Cubic feet.	1884. Value.	1885. Cubic feet.	1885. Value.	1886. Cubic feet.	1886. Value.	1887. Cubic feet.	1887. Value.
Free of duty.										
Wood, unmanufactured, not elsewhere specified:										
Firewood	16,260,864	$397,391	16,249,824	$373,912	15,597,216	$338,806	16,910,400	$349,134	16,464,288	$327,349
Logs and round timber	7,673,100	613,847	5,617,300	449,382	4,811,800	384,948	5,748,000	459,843	7,338,400	587,073
Railroad ties	a10,'77,617	622,657	6,764,359	382,719	3,850,301	187,168	7,265,685	377,443	8,424,833	484,945
Shingle and stave bolts	7,456,080	186,402	9,933,680	248,342	4,847,080	121,177	5,374,280	134,357	5,254,800	131,370
Ship timber	202,468	50,617	190,016	47,504	58,652	14,663	156,076	39,019	181,988	45,497
Ship planking	86,436	28,812	125,829	41,943	63,369	22,123	56,571	18,857	98,094	32,698
Hop poles	.....	.....	323,200	40,399	150,200	18,780	100,000	12,511	26,224	3,278
Wood pulp	.....	19,132	.....	5,941	.....	9,637	.....	5,897	.....	7,381
Charcoal	.....	.....	.....	56,765	.....	47,334	.....	36,849	.....	47,353
Hemlock bark	.....	343,559	.....	364,410	.....	288,979	.....	236,198	.....	272,956
Dutiable.										
Wood, unmanufactured, not elsewhere specified	2,593,616	324,202	647,688	80,961	311,680	38,960	206,616	25,827	142,896	17,862
Timber	156,556	18,990	71,812	8,512	73,290	11,712	20,231	2,221	9,967	1,025
Lumber:										
Boards, planks, deals, etc	43,754,061	7,009,644	44,725,966	6,987,694	41,854,165	6,189,781	39,933,981	5,639,813	40,297,865	5,825,320
Clapboards	918,933	30,224	841,253	28,785	998,807	41,827	1,303,413	59,389	1,397,450	58,953
Hubs, posts, lasts, and rough blocks	370,111	66,620	337,167	60,690	327,993	59,039	337,161	60,615	260,867	46,956
Laths	2,779,648	205,513	2,982,784	257,529	2,477,008	199,819	2,457,216	198,756	3,051,728	241,077
Pickets and palings	510,400	60,494	375,920	57,596	375,920	51,027	406,080	61,318	388,800	32,907
Shingles	1,469,650	281,831	1,206,282	215,454	976,556	158,043	1,107,414	171,523	1,254,176	185,611
Shooks and packing boxes	149,784	37,446	336,264	84,066	280,060	70,015	421,796	105,449	463,996	115,999
Staves	109,538	27,410	1,040,546	280,150	942,318	253,703	1,002,716	269,961	1,129,258	304,031
Bark extracts, chiefly hemlock	.....	127,316	.....	31,686	.....	19,656	.....	9,273	.....	51
Sumac	.....	459,759	.....	668,440	.....	504,289	.....	564,276	.....	466,378
Cork and cork bark, manufactured b	.....	91,400	.....	158,419	.....	147,132	.....	176,679	.....	209,532
Walking sticks	.....	.....	.....	14,560	.....	11,628	.....	9,079	.....	8,101
Matches	4,064	12,192	116,018	348,055	35,465	106,395	11,396	34,187	8,486	25,458
Manufactures: a										
Casks and barrels		2,576		1,896		1,494		1,224		1,780
Cabinet ware and furniture		283,291		295,064		268,810		308,191		387,234
Osiers and willows, peeled and dried	1,957,208	54,424	1,591,322	51,691	1,411,916	28,665	1,367,690	15,164	1,602,744	18,516
Osier and willow baskets		262,056		237,834		202,663		238,380		312,179
All other manufactures		865,559		607,007		557,305		462,809		482,349
Free of duty.										
Cabinet woods: b										
Box	.....	38,953	.....	83,921	.....	223,015	.....	72,403	.....	35,202
Cedar	.....	424,058	.....	568,866	.....	520,605	.....	520,184	.....	263,825
Ebony	.....	47,824	.....	63,614	.....	26,311	.....	69,043	.....	51,211
Granadilla	.....	814	.....	365	.....	432	.....	2,807	.....	1,685
Lancewood	.....	12,336	.....	7,051	.....	1,117	.....	16,910	.....	23,975
Lignum-vitæ	.....	101,305	.....	45,206	.....	8,698	.....	42,362	.....	66,513
Mahogany	.....	466,809	.....	772,710	.....	592,771	.....	479,861	.....	653,473
Rose	.....	313,348	.....	157,266	.....	52,306	.....	46,957	.....	62,308
Sandal	.....	10,529	.....	4,009	.....	654	.....	2,598	.....	1,339
Satin	.....	.....	.....	5,834	.....	5,984	.....	12,641	.....	9,528
All other cabinet woods	.....	465,814	.....	315,173	.....	226,491	.....	219,585	.....	252,084
Cork wood or bark, unmanufactured	.....	934,427	.....	935,871	.....	879,243	.....	891,392	.....	1,239,247
Total	96,830,134	15,299,481	93,477,230	15,447,292	79,446,796	12,893,405	84,186,712	12,461,985	87,796,860	13,341,609

a Estimated from values reported, actual measurements not being given. The principal object in the compilation of these tables has been to show the quantity of forest material involved in our exports and imports. All estimates of quantity are made on the basis of the cubic foot as a common standard. Where the reports from which these tables are compiled do not give quantities, but only values, the quantities have been estimated from the values. In the case of manufactures, such as barrels, cabinet ware, etc., articles are estimated to have one-third of their value in material, and this is reckoned as worth 25 cents per cubic foot. Round timber is reckoned at 8 cents per cubic foot, ship timber at 25. Shingles are estimated at 14 cubic feet per 1,000, and lath at 16 feet per 1,000.

b It will be seen by a comparison of figures that only about one-fifth in value of all importations of wood and wood products consists of articles not producible in this country.

From the preceding tabulation of the annual cut of timber it appears that about three-fourths of our consumption comes from coniferous growth—pines, spruces, firs, hemlock, redwoods, cedar, etc.

This particular portion of our resource is, therefore, the most important, and again the white pine has so far formed the bulk of these supplies. It will, therefore, appear appropriate to reproduce such portions of Senate Document No. 40, furnished by the Division of Forestry, as will elucidate the economic condition of this particular part of our resource.

CONSUMPTION AND SUPPLIES OF CONIFEROUS WOODS.

Ever since the publication of the statistics of the Tenth Census regarding the white pine timber standing—nearly fifteen years—there has been a contention as to their correctness. Time has proven their extreme inaccuracy, for, while then only eight years' supply was supposed to be standing when the annual cut was 10,000,000,000 feet, we have, with an increased cut, lumbered white pine for sixteen years and still there is a considerable quantity left.

Yet at last the end is visible, and even the most sanguine can not longer hide the truth that within the next decade we shall witness the practical exhaustion of this greatest staple of our lumber market.

As stated before, even now there are really no statistics upon which to base a correct prognostication as to the date of this exhaustion. Estimates only are available, and estimates of standing timber are proverbially unreliable, mostly underestimates, and always to be taken with caution. Furthermore, if an estimate of the duration of supplies of a special kind is to be made, it is necessary not only to know the supplies and the present cut, but also to foresee the changes in the cut, the replacement in the market by other kinds, and the economies that may be practiced in the methods of logging; as, for instance, by the reduction in the size acceptable for saw logs, by cutting smaller trees, by the use of band saws, and by closer utilization generally, whereby the duration of supplies can be lengthened.

Thus, while the estimates of the Tenth Census were based on a minimum log of, say, 10 or even 12 inches diameter, in the present practice 8-inch and even 5-inch logs are used; while in 1880 hemlock went begging and whitewood had not yet been found to answer as a good substitute for white pine, and Southern pine had not yet begun to compete, the interchangeableness of all these species in the market now renders the forecast still more complicated.

Nevertheless, it has become apparent that while white pine will be cut in the United States for many decades, as owners of the stumpage control their holdings, the enormous amounts which have hitherto been cut annually can not be had beyond the next five or six years, even with Canada to help in eking out our deficiencies.

CONSUMPTION.

From the statistics of the cut since 1873, compiled by the Northwestern Lumberman, it appears that since that year the stupendous amount of 154,000,000,000 feet, B. M., and 83,000,000,000 shingles, or altogether in round numbers 165,000,000,000 feet of white pine has been cut in the States of Michigan, Wisconsin, and Minnesota; and this total may be readily increased, by allowing for cuts in other parts of the country, to over 200,000,000,000 feet, B. M., which this single species has yielded to build up our civilization in the last twenty-three years, or in the last ten years at the rate of eight to nine billion feet, an amount to produce which continuously at least 30,000,000 acres of well-stocked and well-kept pine forest would be required.

Divided for convenience and comparison into six-year periods, the cut in the Northwest appears to have been as follows, according to the source cited:

White pine sawed by mills of Michigan, Wisconsin, and Minnesota.

[In billion feet, B. M., round numbers.]

	1873–1878.	1879–1884.	1885–1890.	1891–1896.
Lumber	23	40	48	44
Shingles (1,000=100 feet, B. M.)	2	3	3	2
	25	43	51	46

A total of 165,000,000 feet, B. M.

From 1873, when the cut was about 4,000,000,000 feet, the draft on this resource was constantly increased until 1892, when it reached its maximum, nearly 9,000,000,000 feet, B. M., and 4,500,000,000 shingles. Then a gradual decline began to 7,600,000,000 feet in 1893, 6,750,000,000 feet in 1894, rising once more to over 7,000,000,000 in 1895, and reaching the lowest output in 1896, with 5,500,000,000 feet; shingle production declining similarly to 1,500,000,000, which, translated

into board measure, raises the requirements for that year to little less than 7,500,000,000 feet. This decline does not necessarily indicate any giving out of the supply, but might have been due, and probably was due, to business depression generally and to the competition of other kinds of lumber and shingles.

The total output of white pine in 1890, before the maximum was reached and when the cut of the Northwest was recorded for lumber and shingles as a little over 9,000,000,000 feet, was placed by the competent agent of the Eleventh Census, in charge of the statistics of lumber manufacture, at 11,300,000,000 feet of white pine and Norway pine, or about 25 per cent as coming from other regions, while hemlock, spruce, and fir were estimated as furnishing 7,900,000,000 feet, so that our requirements of these classes of timber may for ordinary years be placed in round numbers at 20,000,000,000 feet.

In discussing the question of duration of supplies it can, as stated before, be reasonably done only by considering at the same time all supplies of a similar nature—namely, of the white pine, Norway pine, spruce, and hemlock at least—which can be and are used more or less interchangeably, and will be still more so in the future, to meet our immense requirements for this class of material. That these requirements are not to remain stationary, but have a tendency to increase, may be seen from the development of the wood-pulp industry.

While in 1881 the daily capacity of wood-pulp mills was less than 750,000 pounds, it had more than doubled in 1887, and then increased steadily, doubling almost every three or four years, as follows:

	Pounds.		Pounds.
1887	1,687,900	1892	5,136,300
1888	2,153,500	1893	6,495,400
1889	3,474,100	1894	7,231,900
1890	4,012,200	1895	9,027,000
1891	4,497,200		

This last figure may be conservatively estimated to correspond to an annual consumption of probably 800,000,000 feet, B. M., of material.

There was imported from 1891 to 1896 wood pulp to the value of $10,337,659, as follows:

1891	$1,902,689
1892	1,820,143
1893	2,908,884
1894	1,664,547
1895	984,692
1896	1,056,704
Total	10,337,659

SUPPLIES.

While the above figure of 20,000,000,000 feet, B. M., gives a fair idea as to average consumption, which may vary perhaps by 10 per cent one way or the other, we are much less certain as to supplies standing.

For Minnesota the chief fire warden of the State has attempted a canvass, the result of which would indicate nearly 18,000,000,000 feet as standing in the State, including Norway pine, the estimate having been made for 1895. This has been criticised by competent judges as much too high; nevertheless, adding the estimates of all other kinds of coniferous wood, some of which as yet remains unused, it is thought that a statement in round numbers of 20,000,000,000 feet of coniferous wood in Minnesota fit for lumbering, though large, would be reasonably enough near the truth for our purposes in forecasting the probabilities.

For Wisconsin we have a very close estimate, made by the Division of Forestry in 1897 and fully described in Bulletin No. 16 of that Division. According to this canvass the amount of white pine standing is still 15,000,000,000 feet, B. M., and of all coniferous wood 29,000,000,000 feet, while the writer in the Senate document had estimated it at 30,000,000,000 feet.

For Michigan a canvass from township to township has been made by the commissioner of labor of the State for 1896, which develops an area of 2,250,000 acres in pine and hemlock.

If the average stand per acre, which the census of 1890 showed as 6,000 feet for white pine, is applied to the whole area, the amount of timber standing would be 15,000,000,000 feet, which, for

safety, we may increase by 20 per cent, or say 18,000,000,000 feet, of which 6,000,000,000 would be white pine.

For Pennsylvania the partial returns of the commissioner of forestry would make an estimate of 10,000,000,000 feet pine and hemlock appear highly extravagant. In a private communication he estimates the standing timber of white pine at 500,000,000, of spruce at 70,000,000, and of hemlock at 5,000,000,000 feet, B. M.

For New York, without much basis, 5,000,000,000 may be allowed as an extravagant figure, with a cut of not less than 500,000,000 feet; another 3,000,000,000 for New Hampshire; and, with a closer estimate, based on figures given by the forest commissioner of Maine, that State may be given at best not to exceed 10,000,000,000 feet of spruce, pine, and hemlock.

It is well known that in the "Pine Tree" State the white pine is long since reduced to a small proportion of the coniferous wood standing. The spruce country is confined to the elevated northern half of the State, north of a line from the White Mountains to Mars Hill, with a spruce-bearing area of probably less than 6,000 square miles. The stand on the two main spruce-producing drainage basins, the Kennebec and Androscoggin, has been estimated at round 5,000,000,000 feet, B. M., with a present cut of round 350,000,000 feet. Partial statistics of the cut would indicate a total cut of coniferous woods in Maine of not far from 500,000,000 feet in 1895 and preceding years.

In all these estimates of standing timber the writer has leaned toward extravagance rather than understatement, and thus the total is found to add up 100,000,000,000 feet of coniferous growth in the Northern States, of which less than half is pine, to satisfy a cut of at least 18,000,000,000 to 20,000,000,000 feet per annum.

The writer does not say that in less than six years every stick of pine, spruce, and hemlock will be cut, for such figures as these do not admit of mathematical deductions, but the gravity of the question of supply is certainly apparent. Even doubling the estimates, it is found that, with the present rate and method of cutting, ten years would exhaust our virgin timber of these classes. We should add that much more intimate knowledge exists now regarding these supplies than was possible in 1880, when much of the country was still unopened and unknown.

OTHER CONIFEROUS SUPPLIES.

The Southern pines, to be sure, will enter more largely into competition, as also the cypress and other coniferous woods of the South.

The entire region within which pines occur in the South in merchantable condition comprises about 230,000 square miles, or, in round numbers, 147,000,000 acres; for land in farms, 10,000,000 acres must be deducted, and allowing as much as two-thirds of the remainder as representing pine lands (the other to hard woods), we would have about 90,000,000 acres on which pine may occur. An average growth of 3,000 feet per acre—an extravagant figure when referred to such an area—would make the possible stand 270,000,000,000 feet, provided it was in virgin condition and not largely cut out or culled. Altogether, the writer has reached the conclusion that, adding all other coniferous wood in the South, an estimate of 300,000,000,000 feet would be extravagant, which, added to the Northern supply of coniferous wood, gives a total supply of 400,000,000,000 feet to draw from in the Eastern United States; and as the entire cut of these classes of wood appears now to be not less than 25,000,000,000 feet a year, and probably is nearer 30,000,000,000, it may be stated with some degree of certainty that not fifteen to twenty years' supply of coniferous timber can be on hand in the Eastern States.

In 1886 the writer ventured a statement that there was 600,000,000,000 feet of coniferous growth in the Eastern States; the cut was then estimated at 12,000,000,000 feet. If an average cut of 20,000,000,000 for the last ten years be allowed, which is reasonable, the present estimate of 400,000,000,000 standing would lend color to the approximate correctness of these figures.

If the inquiry is extended to the coniferous growth of the Pacific coast, which, in spite of the distance, must finally come to our aid, only partial comfort will be found. The writer's estimate of 1,000,000,000,000 feet standing has been by competent judges declared extravagant. The annual cut on the Pacific coast approaches certainly 4,000,000,000 feet; hence, adding these figures to those obtained for the East, with 1,400,000,000,000 feet standing at best, and a cut of at least 30,000,000,000 feet per annum, there would appear to be, under most favorable contingencies, not

more than forty to fifty years of this most necessary part of our wood supply in sight if the same lavishness in the use of it is continued.

To be sure, there is some new growth and reproduction going on. The probability as to the former is that decay and destruction by fire offset the accretion on the old timber of coniferous growth, and no one familiar with our forest conditions and present methods will indulge in a hope that the reproduction and young growth can materially change the results. Long before any new reproduction can have attained log size we will have got rid of the virgin supplies.

CANADIAN SUPPLIES.

As to importations, there is practically only one country from which such timber can be obtained—Canada.

The statistician of the department of agriculture of the Dominion of Canada in 1895 estimated the white pine standing at 37,300,000,000 feet, with an annual cut of nearly 2,000,000,000 feet, including spars, masts, shingles, etc., which, as will readily be seen, can not materially change the position stated before, namely, that the next decade may witness the practical exhaustion of this greatest lumber staple. Even allowing 10,000,000,000 feet of merchantable spruce, which may be found in New Brunswick and Nova Scotia, such allowance can not appreciably retard this exhaustion, since the total annual cut of Canadian coniferous wood exceeds 5,000,000,000 feet. Fifty per cent may be readily added to the estimates of standing timber in eastern Canada, thus assuming 75,000,000,000 feet as on hand, and still Canada's cut alone will exhaust her resources in fifteen years, and this country will assist her to get rid of it in less time.

So far the importations from Canada, although rapidly increasing, have been insignificant when compared with our home consumption. The importations of all kinds of forest products and wood manufactures have been hardly over 1 per cent of our own production, and, if we confine the inquiry to coniferous material only, the proportion of the importation of this class of materials rises to hardly 5 per cent of our home production of the same kinds.

To arrive at an idea of the extent to which we have so far drawn on our neighbors for coniferous supplies, an attempt has been made in the following table to segregate from the trade and navigation reports of the Dominion of Canada those items which have reference to this discussion, translating into board measure approximately the returns given in other measures. These figures are probably somewhat below the truth, but are sufficiently accurate for the present purpose, and are moreover the only ones available.

Exports of coniferous products from Canada to United States.

[In millions of feet, B. M., rounded off.]

Coniferous products.	1877–1882.	1883–1888.	1889–1894.	1892.	1893.	1894.	1895.	1896.
Logs:	*6 years.*	*6 years.*	*6 years.*					
Hemlock	5.5	9.5	20.0	5.0	5.9	5.2	2.2	4.8
Spruce	9.0	26.6	86.9	23.0	21.0	17.9	25.0	15.2
Pine	2.2	4.6	504.5	74.0	127.0	277.9	212.2	157.7
Total logs	16.7	40.7	611.4	102.0	153.9	301.0	239.4	177.7
Lumber:								
Deals	31.5	108.7	204.5	53.0	51.0	42.5	44.2	48.8
Laths	43.5	64.8	250.7	38.7	89.4	42.8	44.0	52.3
Boards, scantling, etc	965.8	1,132.9	3,098.1	651.4	759.1	1,018.3	549.5	720.5
Masts, spars, and other	1.4	.8	.7	.2	....	....	....	....
Shingles	14.9	21.8	132.2	33.4	40.3	36.5	65.8	45.7
Timbers	3.9	1.6	165.5	....	....	....	....	....
Pulpwood blocks	(*a*)	(*a*)	(*a*)	30.0	62.0	61.5	76.3	100.0
Total manufactured wood	1,061.0	1,330.6	3,851.7	806.7	1,001.8	1,201.6	779.8	967.3
Total coniferous products	1,077.7	1,371.3	4,463.1	908.7	1,155.7	1,502.6	1,019.2	1,145.0

a Too small to be stated in millions of feet, B. M.

It will be seen that each six years' period shows an increase, and that the exports of the last three years were only 25 per cent lower than those of the six preceding years. The largest imports were recorded for 1894, when nearly 1,250,000,000 feet partly manufactured coniferous wood and 300,000,000 feet of logs of conifers were imported. This latter importation increased steadily up

to that time, furnishing raw material mainly to our Michigan mills, whose home supply is largely gone.

Regarding the importations of logs, it is interesting to observe that they increased in quantity, without reference to the existence or absence of the export duty which the Canadian Government imposed in 1886 and abolished in 1891, and the price per M feet also seems uninfluenced. The necessity for these supplies to our mills, especially the mills of the Saginaw (Michigan) district, began to assert itself in 1886, the very year the export duty was imposed to prevent, if possible, these exports of raw material, and has grown constantly, the decline in 1895 and 1896 simply marking the general business depression.

Logs imported from Canada.

Year.	Pine logs.			Spruce logs.			Hemlock logs.		
	Quantity, M feet.	Value.	Price per M feet.	Quantity, M feet.	Value.	Price per M feet.	Quantity, M feet.	Value.	Price per M feet.
1884	974	$8, 012	$8. 23	6, 820	$31, 793	$4. 66	4, 818	$19, 168	$3. 98
1885	380	2, 300	6. 05	11, 165	49, 449	4. 43	3, 629	14, 752	4. 07
1886	2, 869	24, 452	8. 52	17, 541	81, 874	4. 67	6, 881	28, 076	4. 08
1887	6, 350	49, 242	7. 75	17, 526	88, 773	5. 65	4, 206	17, 447	4. 15
1888	468	3, 875	8. 28	20, 714	99, 450	4. 80	4, 512	18, 383	4. 07
1889	10, 839	94, 287	8. 70	20, 360	137, 298	6. 74	6, 420	24, 261	3. 78
1890	32, 144	261, 626	8. 14	26, 073	156, 898	6. 02	2, 952	12, 288	4. 17
1891	36, 699	313, 281	8. 54	28, 494	158, 334	5. 56	2, 210	9, 802	4. 44
1892	73, 963	651, 540	8. 81	23, 404	141, 168	6. 02	5, 057	21, 426	4. 24
1893	127, 084	1, 056, 355	8. 32	21, 103	123, 254	5. 84	5, 880	26, 036	4. 43
1894	277, 947	2, 359, 951	8. 49	17, 926	107, 250	6. 00	5, 217	19, 713	3. 77
1895	212, 231	1, 860, 319	8. 77	25, 095	90, 990	3. 64	2, 217	9, 017	4. 06
1896	157, 400	1, 423, 489	9. 06	15, 182	86, 075	5. 67	4, 761	18, 607	3. 90

It will be evident from these statements that our virgin coniferous supplies must share the fate which the buffalo has experienced, unless a practical application of rational forestry methods and a more economic use of supplies is presently inaugurated. Since coniferous wood represents two-thirds to three fourths of our entire lumber-wood consumption, and its reproduction requires more care and longer time than that of hard woods, the urgency of changing methods in its use and treatment will be apparent.

No more striking statement of the decline in white-pine supplies could be made than to cite the number of feet in logs which passed the nine leading booms in the lower peninsula in Michigan in 1887, namely 2,217,104,985 as against 505,134,656 feet in 1893, a decrease of nearly 80 per cent, chargeable no doubt in part to other modes of transportation, but nevertheless foreshadowing unmistakably the practical exhaustion of supplies.

Another indication of the waning of supplies may be found in the increase of prices paid for stumpage. While, owing to improvement in means of transportion machinery and mill practice and to the close competition of mills, the increase in the price of lumber has been comparatively small except for the best grades, which are becoming scarcer with the reduction in the size of the average log than the poorer grades, the prices paid for the trees in the woods, the stumpage has more than doubled for each decade from 1866 to 1886, as appears from the table given above. At present it would probably be difficult to find any stumpage desirably located at the highest price prevailing in 1887, and this year (1898) stumpage even of the southern pine has gone up to $4.00 and $6.00 per M feet.

Returning now to a consideration of the consumption of wood materials in general we can summarize with the statement that our consumption at present of all kinds, sizes, and description, including the enormous firewood supplies of a round 180,000,000 cords, can not fall short of 25,000,000,000 cubic feet of forest-grown material, counting in the waste in the woods and the mills and loss by fire. That means a consumption of 50 cubic feet per acre of forest, or 350 cubic feet per capita.*

Considering that in the well-kept forests of Germany, where reproduction is secured by

*The largest part of this consumption is for firewood. According to the census of 1880 the consumption of firewood must then have been 280 cubic feet per capita (figuring 100 cubic feet solid to the cord), and this amount has probably not been reduced during the last decade. This firewood is not, as in older countries, made up of inferior material—brush and small fagots—but is, to a large extent, split body wood of the best class of trees.

skillful management, the total growth per acre, brush and branch wood included, averages only 55 cubic feet, it needs no argument to prove that we are cutting yearly far more than can be reproduced, especially when we consider that while in Germany all inferior material is utilized, we use even for firewood purposes good-sized material, body wood, hardly inferior to saw timber, so that the comparison should be rather with the production of what the Germans call "derbholz," including all material over 3 inches, which averages hardly 38 cubic feet per acre and year.

The inadequacy of our supplies for continuous use at the present rate, it must appear, is unquestionable, unless we apply more rational methods of treating our forest areas.

That for a time at least decrease of consumption is not likely to occur we may learn from a comparison of figures of consumption from decade to decade, which indicate an increase of 30 per cent or more.

Estimates of value of forest products used in 1860, 1870, 1880, and 1890.

[Including all raw, partially manufactured, wholly manufactured wood products, fuel, and naval stores; estimated upon the basis of census figures, and other sources of information.]

Articles.	1860.	1870.	1880.	1890.
Mill products, rough and partly finished	$155,000,000	$340,000,000	$400,000,000	$438,000,000
Cut on farms for home use	45,000,000	52,000,000	55,000,000	50,000,000
In manufactures using wood	50,000,000	100,000,000	110,000,000	150,000,000
Railroad building	6,000,000	14,000,000	30,000,000	40,000,000
Fuel	135,000,000	210,000,000	328,000,000	350,000,000
Total	*a*391,000,000	716,000,000	923,000,000	1,028,000,000

a Probably 25 per cent underestimate.

Considering the consumption in relation to the population, we find by comparison with other nations of equally civilized conditions that, if our figures are approximately correct, our per capita consumption is from eight to twenty times more than the per capita consumption of Germany, France, or England. For while we figure 350 cubic feet of all kinds for our people, Germany uses 44, France 32, and England 15 cubic feet per capita. And if we exclude the more uncertain firewood consumption and estimates of waste, and compare only the most important part of the consumption, we find the relation not less striking; for while we consume nearly 80 cubic feet of log timber, equal to 50 cubic feet of sawed goods, or between 500 and 600 feet B. M., per capita annually, Germany requires only 15 cubic feet of sawed material, or about 150 feet B. M.; France 8.3 cubic feet, and England, importing nearly all her wood materials, can get along with one-quarter of our consumption. We see, then, that there is a wide margin for saving in wood supplies by substituting iron and stone in our structures; by using preservative processes with our railroad ties and other timbers; by using our wood materials with more discretion and knowledge.

Our enormous annual loss by fires, largely due to the many wooden structures, and giving rise to a destruction of property estimated at $100,000,000, constitutes a drain on our forest supplies which can be largely avoided.

FOREST FIRES.

Another cause of useless and wasteful decimation of forest supplies is occasioned by the yearly conflagrations, which destroy not acres but square miles of standing timber and the young growth, and even the soil, the fertility, an accumulation of centuries of decaying leaf mold.

Regarding the loss by fire no adequate conception can be formed. Fires are of such general occurrence that only the larger conflagrations are noticed, and it is difficult to obtain reports as to their extent and destructiveness.

In the South the foolish custom of annually burning off the old grass in order to gain a fortnight's earlier pasturage still prevails and gives rise to widespread destruction, which is increased by the coniferous composition of the larger part of these areas and the additional danger occasioned by turpentine orchards. In the West carelessness of campers seems to be the principal cause of fires, which, owing to the dryness of the climate and absence of population interested in stopping the conflagrations, assume frightful dimensions and often not only destroy square miles of timber, but endanger the lives and property of settlers.

From locomotives without spark arresters or carelessly handled at the ash pit comes the greatest danger in the East. To estimate even the direct loss or damage from this source is well-nigh impossible, much less the indirect loss, which consists in the destruction of the forest floor, the handing over of the ground to worthless brush, brambles, and inferior tree growth, or, as happens in some regions, the burning of the soil down to the rock, leaving an irredeemable waste. Thus the accumulation of centuries—it takes from three to five centuries to make a humus soil 1 foot in depth—is destroyed in one brief season by carelessness.

In the census of 1880 an attempt was made to ascertain the extent of the fires and the consequent loss in money value. Upon unsatisfactory and partial returns a total of over 10,000,000 acres was reported burned, with a loss of over $25,000,000 in value.

A canvass made by the Division of Forestry some years ago, which was highly unsatisfactory in its returns, these being vague and reporting only very partially, shows that in the districts reporting more than 12,000,000 acres of woodland were burned over during 1891. The report showed log timber killed 473,387,000 feet B. M. and damage from forest fires to other than forest property to the extent of $503,590, besides injury to valuable forest growth difficult to estimate. What proportion of the actual destruction these reports represent it is impossible to tell. They show, however, that in spite of the growing sentiment against such useless waste the nuisance has hardly abated in the last ten years. The loss from prairie fires to crops, tree growth, buildings, and other property was reported by the same correspondents at $1,633,525.

In some years these losses by fire are, to be sure, much greater than in others, especially for given localities. Thus the fire which raged around Green Bay, in Wisconsin, during the latter part of September and beginning of October, 1871, is reported to have utterly devastated 400 square miles of territory, several villages being wiped out, at least 1,000 people perishing, and 3,000 being left destitute; the damage being estimated at $3,000,000, not including that of the thriving village of Peshtigo, with 2,000 inhabitants.

Another fire in Wisconsin (around Phillips) and in neighboring Minnesota, still in our memory, occurred during the drought of July and August, 1894, the latter known as the great Hinckley fire, when the estimate of loss of life exceeded 1,000, although it is only known that 437 were surely lost, while over 2,000 were made homeless, the material loss, not including the timber, being estimated at $750,000.

Another most destructive fire occurred in 1881 in Michigan, when the fire ran over forty-eight townships in the peninsula between Lake Huron and Saginaw Bay, and a belt of timber country, partly settled, 60 miles in length and 10 to 30 miles in width, comprising a round million acres, was absolutely destroyed. The number of people killed was 138 and the value of property destroyed $2,000,000, not taking into account the timber and the loss to the future, for this region remains still to a large extent a mere brush waste.

In comparison with our figures of bona fide consumption the direct loss in material is but a small matter, perhaps 2 to 3 per cent of the total value of forest products, but the indirect loss can hardly be overestimated. This lies not only in the destruction of the fertility of the soil, but in discouraging more conservative forest management on the part of forest owners, while the constant risk from fire is an incentive to turn into cash as quickly as possible what is valuable in the forest growth, leaving the balance to its fate.

There is a crying need in the United States for economic reform in this matter of playing with fire. If the fire nuisance could be reduced to the unavoidable proportion, half the forestry problem would be solved.

FOREST SUPPLIES.

Having traced our consumption of forest supplies, it remains to consider the condition of the resource from which this consumption is to be drawn. We have to distinguish here between virgin supplies now ready for the ax—the standing timber—and new growth to supply future wants.

Again we have, unfortunately, no statistics which would permit us to speak with assurance on this question. As regards the coniferous supplies of standing timber we have already made computations, showing that 100,000,000,000 feet for the North, 300,000,000,000 feet for the South, and less than 1,000,000,000,000 for the West, or altogether about 1,400,000,000,000 feet B. M., would have to be considered an extravagant estimate to meet the estimated cut of this class of materials of 30,000,000,000 feet per annum.

An estimate based on reported average cut per acre—which, to be sure, is extremely variable, not only from acre to acre but also from time to time as the standard of marketable logs changes—would bring the total of the timber standing ready for the ax to about the following figures as very rough and probably very liberal approximations:

	Feet B. M.
Southern States	700,000,000,000
Northern States	500,000,000,000
Pacific coast	1,000,000,000,000
Rocky Mountains	100,000,000,000
Total	2,300,000,000,000

To arrive at these figures we have assumed that the amount of timber to be found on the total forest area reported, as given in the preceding table, may be set, as an average for every acre, at 4,000 feet B. M. for the Southern States, 6,000 feet for the Northern States, somewhat less than 20,000 feet for the Pacific coast States, and 2,000 feet for the Rocky Mountains.

We admit that these are only guesses based upon personal observation, conversation with lumbermen, and such incomplete records as could be inspected. It is believed that the figures are leaning toward overstatement rather than the other way. For the purpose of estimating the likelihood of continued supplies these figures will suffice to show that the resource is easily exhaustible. When it is considered that the bulk of the most important supplies (the coniferous trees) is to be found in the far West, thousands of miles away from our centers of civilization, the aspect of the economic conditions is not assuring.

As to replacement, by young growth, of supplies cut, the possibility of estimate even is precluded, and we can only state in general that by culling the valuable kinds and leaving the tree weeds to occupy and shade the ground, as is done through all the hard-wood region, the reproduction of valuable species is almost prevented; that the reproduction from the stump in the coppice, which occupies the largest share of the forest area of New England and the Eastern Atlantic States, does not furnish saw material, but only firewood and small-dimension stuff; that much of the young growth of valuable kinds, especially the pines in the South, which, if left undisturbed, would readily and rapidly fill the gaps, is burnt again and again by recurring fires, the same cause sweeping out of existence not only the young growth but the standing timber on the Pacific slope and the Rocky Mountains.

For a more complete description of a specific area, the State of Wisconsin, its past and present forest conditions and future promises, we refer to the following extracts from Bulletin No. 16 of the Division of Forestry, giving in detail the results of a survey of the forestry conditions and interests of that State by Prof. Filibert Roth, made in 1898. It is a typical picture, which will serve in its general aspects for the entire great lumbering section of the Northwest.

FOREST CONDITIONS OF WISCONSIN.

PHYSIOGRAPHY.

The part of the State lying north of a line from Green Bay to St. Croix, with the counties of Portage, Wood, and Jackson as southern outposts, contains practically the entire stand of lumber-size timber of both pine and hardwoods in Wisconsin. Nine-tenths of the area presents a broad slope rising from southeast, south, and southwest to a flat divide which runs east and west close to Lake Superior, and one-tenth is occupied by a steeper slope from this divide to the lake. About 43 per cent of this area is formed by an upland plain with low flats, not over 5 per cent is hilly, and the rest is ordinary rolling country with considerable areas of low but steep rolling, "choppy," "pot hole," or "kettle" land. The drainage is mostly excellent in spite of the fact that this area contains over a thousand lakes and is nearly 12 per cent swamp land. Over a large part of the territory it is impossible to get 5 miles away from a driving stream, and nearly all creeks have ample fall. Over 25 per cent of the area is drained by the Chippewa and its tributaries, about 21 per cent by the Wisconsin, and 14 per cent by the St. Croix.

The soil and subsoil of about 56 per cent of this territory is a deep gray loam, more or less mixed with gravel; a deep fertile red clay skirts Lake Superior and sandy lands fringe its southern and southwestern edge, while three large islands of sandy land, one on the upper St. Croix, another on the head waters of the Wisconsin, and the third stretching from the Menominee to

Lake Shawano, interrupt the loam land area. Classed from the farmer's standpoint, about 22 per cent of the land must be called good farm land, about 40 per cent medium, while fully 37 per cent should never be cleared of woods. The climate is cold, winters long, spring nearly wanting, summer short but warm, and fall long and cool. As indication of the climate it may be said that hickories practically do not occur; that white oaks are restricted to the southern and drier western parts; ordinary corn does not usually ripen in the greater portion of the territory, and apple trees have so far largely failed even in the more southern counties.

OWNERSHIP.

Of the 18,500,000 acres of territory under consideration less than 7 per cent is cultivated, about 24 per cent held by actual settlers, little more than 1.5 per cent belongs to the State, nearly 5 per cent to the United States (2 per cent to Indians), little over 5 per cent to railway companies, and hardly 1 per cent is held by the counties, who are all anxious to rid themselves even of this small bit of communal property. Of the remaining 63 per cent lumbermen own about 80 per cent, i. e., 50 per cent of the entire area, or about 25 per cent of the area of the entire State belongs to them.

THE FOREST AS IT WAS.

Formerly nearly all of the 27 counties were covered with one uninterrupted forest, and only along the southern and southwestern limits did this forest give way to oak and jack pine openings and brush prairies. On the gray loam lands was a mixed forest of hardwoods and white pine; on all sandy lands and also on most of the red clays of Lake Superior it was pinery proper, i. e., a forest of pines, principally white pine, some Norway, and small amount of jack pine, without hardwoods of lumber size. In the eastern half, which is more humid, the hemlock grew among the hardwoods on most of the gravelly clay and loam lands, but, like white pine under these same conditions, it was found chiefly as mature timber, often nothing but old large trees scattered among the hardwoods, or here and there in compact bodies or groves, without any young growth to indicate active reproduction. Evidently both were here losers in the general struggle for possession of the ground. Besides these three main conifers the balsam and spruce occurred thinly scattered, the latter chiefly in swamps. Most swamps were then timbered, the cedar prevailing in those of the Green Bay region; both cedar and tamarack together, one or the other alone, but more commonly mixed, occupied the majority of swamps, while the tamarack, commonly as a pure but small growth, occupied all those of the southern and southwestern part, and even stocked the openings.

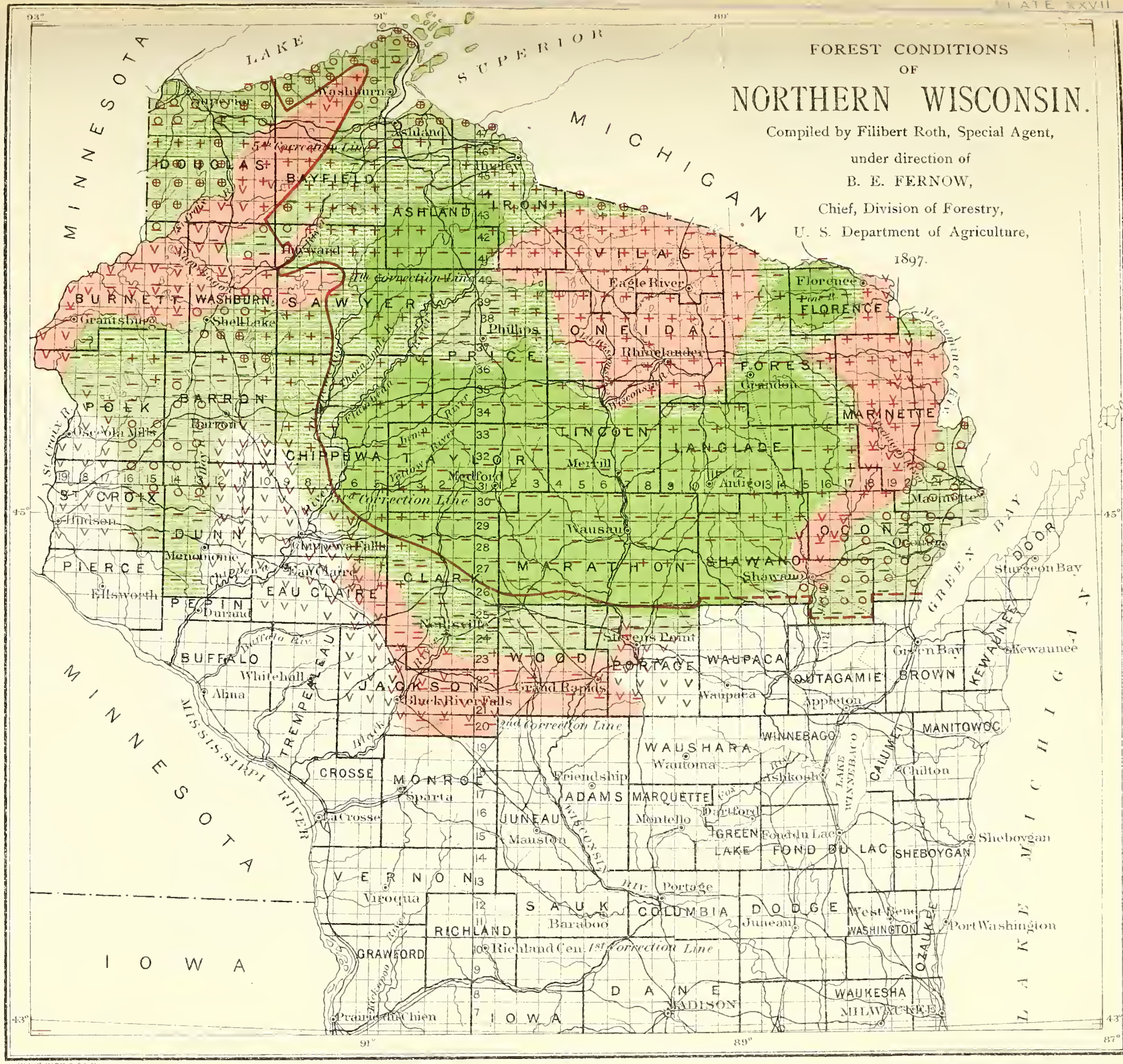
The hardwood forest, heavier, denser, and composed of larger trees in the southern part, and on better soils, while quite thin and scrubby northward and on the lighter gravel lands, was made up of a small number of kinds. Its character varies on the two sides of nearly the same line which limits the hemlock. On the south and west of this line it was an oak forest in which both white and red oak were abundant, oak was predominant, and the birch scarce or wanting; on the north and east of the line birch was the principal hardwood; the white oak was almost wanting, the red oak scattering, and often for many miles the forest was without an oak of any kind or size. Of the other hardwoods, basswood and maple were generally and rather evenly distributed; elm in very variable proportions occurred in most hardwood forests, while ash, generally black ash, was mostly confined to the low flats and swamps.

THE FOREST AS IT IS.

At present the pine is largely cut both from the mixed forests and in the pinery; entire uncut or virgin townships scarcely exist, and in every county large and small "pine slashings" or "stump prairies" are met. In the hardwoods, the oak and basswood, and to some extent the elm, have been culled over large tracts, and entire counties, like Wood and Barron, have been logged over (not logged clean). Besides this the hardwood and still more the hemlock, about most pine slashings, but especially on all lighter soils where the pine predominated, have suffered from fire, and over large areas they are entirely fire killed. Many if not most of the swamps have been burned over, and present all stages from the dense green swamp forest to a bewildering tangle of charred masses of dead and down timber. It is estimated that about 8,500,000 acres, or 45 per cent of the total area, is cut-over land, most of which is also burned over and largely waste.

LEGEND.

- Pinery, on sandy land, without merchantable hardwoods except in small scattered areas.
- + + Pinery with considerable merchantable timber.
- — — Pinery nearly or entirely cut over.
- V V Pinery largely stocked with considerable jack pine.
- Mixed forest of hardwoods, pine, and, in the part east and north of red line, with hemlock. With less than 3,000 feet of hardwood and hemlock per acre of stocked area.
- Mixed forest with 3,000 to 5,000 feet of hardwood and hemlock per acre of stocked area.
- Mixed forest with over 5,000 feet of hardwood and hemlock per acre of stocked area.
- + + Mixed forest with considerable standing merchantable pine.
- — — Mixed forest from which pine has largely been cut.
- — — Mixed forest from which hardwood and hemlock have largely been cut or damaged by fires.
- ⊕ ⊕ Mixed forest, where pine is predominant, the forest resembling pinery.
- O O Mixed forest where pine formerly predominated but is now cut, and the appearance now is that of a pine slashing.
- V V Openings with jack pine woods.
- V V Openings with scrub oak woods.
- Limit of hemlock (area not carried out in the eastern part). To the south and west of this line, the hemlock is not of commercial importance, and the birch is replaced by oak.



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PRESENT SUPPLIES.

Considering present supplies of pine, over 80 per cent of which are owned by lumbermen, it must be borne in mind that in spite of many years of logging but few townships of the better stocked regions, outside of settlements, are logged clean, and counties like Chippewa, Clark, Wood, and Marathon still continue to furnish large quantities of pine logs of all sizes, for it is not so much a lack of good logs as the fact that of late everything is cut clean which has reduced the average size of log to nearly half what it was twenty years ago. It is especially the fragmentary condition of the forest which makes general or wholesale estimates difficult, and causes the opinions on pine supplies to vary within such wide limits. "Most men know little about what their neighbors have," and "the man whose pine supply is nearly at an end, and who finds it hard to buy more stumpage, thinks that everybody shares his trouble." These two statements, variously expressed, may be heard in many places, and fully indicate the difficulty.

The following figures of merchantable supplies still standing, secured by the methods above indicated, are probably quite near the truth, though the total appears still somewhat conservative:

Standing pine, hemlock, and hardwood saw timber in the State of Wisconsin in 1898.

County.	Million feet B. M.			County.	Million feet B. M.		
	Pine.	Hemlock.	Hardwood.		Pine.	Hemlock.	Hardwood.
Ashland	300	300	600	Marinette	1,500	240	240
Barron	150	....	260	Oconto	100	320	280
Bayfield	3,000	280	350	Oneida	1,000	10	24
Burnett	200	....	200	Polk	240	....	300
Chippewa	500	640	1,260	Portage	50	50	100
Clark	200	30	650	Price	200	500	500
Douglas	3,500	....	700	Sawyer	1,500	480	960
Dunn	25	....	400	Shawano	300	550	550
Eau Claire *a*	50	....	....	Taylor	200	950	950
Florence	150	225	385	Vilas	1,500	120	150
Forest	500	480	960	Washburn	350	....	220
Iron	350	275	275	Wood	100	40	300
Jackson	100	....	50	Pierce and St. Croix *a*	....	....	300
Langlade	150	700	875				
Lincoln	250	850	850	Total	16,665	7,640	13,889
Marathon	200	600	1,200				

a Eau Claire is only considered for its pine and St. Croix and Pierce only for hardwoods—the three counties being really outside of the scope of this work.

The detailed estimates given by woodsmen of hemlock and still more of hard woods, vary much more than those of pine. Lack of experience in hard wood, custom of estimating only certain kinds, and discriminating selections in the hardwood markets, which consider only the better sizes or qualities, have led to great differences in figures on yield. The general results above given are very conservative for both hemlock and hard woods in spite of the fact that they represent rather the higher than the average estimates. A more correct view of present supplies may be obtained from a study of the following figures, in which all the wood supplies are arranged in three classes, a portion of the hemlock which, at present rating, is not real saw timber being thrown together with the cedar and part of tamarack and jack pine as a second class. Of these figures it may be said that of the 92,000,000 cords of hardwood fully one-third, or 30,000,000 cords, an equivalent of 15,000,000,000 feet B. M., might still be placed with saw timber.

Wood supplies classified.

Character of wood.	Saw timber.	Secondary timber. Bolt sizes, post, poles, ties, etc.	Cord wood	Character of wood.	Saw timber.	Secondary timber. Bolt sizes, post, poles, ties, etc.	Cord wood.
CONIFEROUS.	*Million feet B. M.*	*Million feet B. M.*	*Millions.*	HARDWOODS.	*Million feet B. M.*	*Million feet B. M.*	*Millions.*
White pine	14,500	....	1,000	Oak	1,380	....	92,000
Red (Norway) pine	2,200	....		Basswood	3,500	....	
Jack pine	....	1,700	1,500	Birch	3,300	....	
Hemlock	7,800	2,500	5,000	Elm	2,200	....	
Tamarack	....	1,400	3,000	Ash	800	....	
Cedar	....	1,300	800	Maple	2,200	....	
Spruce	....	....	....	Others	620	....	
Balsam	....	....	700				
				Total	14,000	....	92,000
Total	24,500	6,900	12,000	Grand total	38,500	6,900	104,000

The above estimates of jack pine, spruce, balsam, tamarack, and cedar must be regarded as rough approximations, since the areas stocked with these timbers are very difficult to ascertain.

What these supplies of pine have been in the past may be inferred from the following calculations, the basis for which have been verified for large areas on the Chippewa, Black, Wisconsin, and Wolf rivers, and may be supposed to understate the truth by at least 10 to 15 per cent.

Probable original stand and present stand of merchantable pine in the State of Wisconsin.

River basin.	Number of towns stocked.	Yield per town.	Yield on river.	Yield on river in per cent of total.	Present stand.	Remarks.
			Million feet.		*Million ft.*	
Black	40	225	9,000	6.9	270	
St. Croix	100	125	12,500	10.7	3,560	Contains much jack-pine barrens.
Red Cedar	40	200	8,000	6.1	475	
Chippewa	175	200	35,000	26.7	3,000	
Wisconsin	172	175	30,100	22.9	2,575	Includes heavy hardwood forest.
Wolf	60	125	7,500	5.7	470	Much hardwood forest.
Oconto	28	125	3,500	2.3	150	Do.
Peshtigo	27	150	4,050	3	500	
Menominee	47	150	7,050	5.4	1,500	Only Wisconsin side.
Rivers to Lake Superior	76	150	11,400	8.7	4,200	
Rivers to Green Bay	7	200	1,400	1	....	
Total	772	....	129,500	....	16,700	

Of these 129,500,000,000 feet there is approximately—

	Billion feet.
Standing at present	16.7
Cut between 1873 and 1898	66
Probable cut 1840 to 1873	20
Total accounted for	102.7

Leaving a balance of nearly 27,000,000,000 feet wasted, to which must be added several billions as growth since 1840. Of this enormous waste certainly more than 60 per cent, or about 20,000,000,000 feet, is due to fire, the rest falling to storms, old age, and waste in cutting. This is white pine only.

Besides this injury to pine, fire has killed more than 5,000,000,000 feet of hemlock, at least 1,000,000,000 feet of cedar, and several billions of hard woods, besides large quantities of tamarack, and in addition has killed stands of young sapling pine (under 8 inches diameter) covering many thousand acres which to-day would furnish 5,000,000,000 feet and more of merchantable material.

PRESENT GROWTH.

The amount of timber which at the present time is growing each year on the stocked portion of this area may very safely be placed at about 925,000,000 feet B. M., and is distributed among the several kinds of timber as follows:

	Million feet.
White and Norway pine	250
Jack pine	30
Hemlock	75
Tamarack	30
Cedar	20
Spruce and balsam	20
Hard woods	500
Total	925

Of this growth the greater part is balanced by decay or natural waste, which in all wildwoods necessarily equals growth when large areas and long periods are considered. For white pine, Norway, and jack pine, also for tamarack and cedar in Wisconsin, nearly half the present growth takes place in forests of young, immature timber, since this largely prevails. With the old pine mixed in the hard-wood forest, and especially with hemlock, decay proceeds faster than growth; for spruce and balsam an increase can hardly be assumed, and even in the hardwoods the growth and decay is practically in a state of equilibrium.

PRESENT EXPLOITATION AND MARKET.

At the present time logging of pine is going on in nearly every part of this territory. The average annual cut for the last ten years has been about 3,000,000,000 feet; and pine land, pine stumpage, and logs find a ready market everywhere.

Hemlock is peeled to quite an extent, the bark being mostly used by local tanneries; small quantities are cut to lumber, chiefly dimension stuff, and considerable quantities are converted into railway ties, mining timber, etc., and also into pulp, but on the whole this material is still very much underrated.

The hardwoods are logged and sawn mostly on a small scale. Several hundred small mills are cutting hardwoods, mostly into lumber, much into special sizes and shapes, and large quantities are used for cooperage and wagon stock. Exact figures of the total annual cut in hardwoods are wanting, but 500,000,000 feet is a safe estimate. Spruce and to a less extent balsam are bought for pulp; cedar finds ready market and is extensively cut everywhere for posts, poles, ties, and shingle timber, but tamarack still remains tabooed, and even sappy Norway poles for piling are preferred to this much superior material so that but little tamarack is cut.

From tables just published by the Northwestern Lumberman the following approximation of consumption of lumber is derived. This does not take into account all the scatterred domestic consumption and remains as all such statistics necessarily do, somewhat below the truth:

White pine, Norway pine, and hemlock lumber cut in Wisconsin in 1897.

Locality.	Lumber.	Shingles.	Lath.	Locality.	Lumber.	Shingles.	Lath.
	M. feet.	*Thousand.*	*Thousand.*		*M. feet.*	*Thousand.*	*Thousand.*
Black River	167,455	65,943	25,003	Ashland district	265,350	30,764	15,068
Wisconsin Central	134,132	35,967	14,478	East central Wisconsin	36,670	47,343	3,670
Chicago, St. Paul, Minneapolis and Omaha	185,203	45,744	33,931	Mills below Minneapolis *a*	228,800	70,000	50,000
Minneapolis, St. Paul, and Sault Ste. Marie (Soo)	50,217	10,000	6,300	West Superior district	96,000	11,000	7,000
Wisconsin Valley	398,744	85,920	51,634	St. Croix Valley *b*	100,000	25,000	20,000
Chippewa Valley	274,879	138,382	55,250	Green Bay shore at Menominee *c*	167,000	65,000	30,000
Ashland Branch, Chicago and Northwestern	126,518	78,661	15,214	Mills below Menominee	129,000	41,000	18,000
				Total	2,359,968	750,724	345,548

a One-third of total cut reported credited to Wisconsin. *b* One-half of total cut reported credited to Wisconsin.
c Proportion of cut credited to Wisconsin.

NOTE.—Of the above total cut, 125,000,000 feet was hemlock. Besides this there is more than one-quarter billion feet of hardwoods recorded from mills, which can safely be increased to half a billion for unrecorded cuts at small country mills in the woods.

FUTURE OF PINE MILLING.

How long the present supply of pine will last is impossible to foretell. As the price of stumpage increases and the number of owners (and with this the opportunity to buy pine) decreases, one mill after another drops out. With the concentration of ownership a reduction in output will be the consequence which will continue to the last (if a "last" there be), so that even the present stand is likely not to be cut out in eight to ten years, as might be inferred from a comparison of present supply and cut, but may easily last twenty and more years.

FOREST AND COMMONWEALTH.

The importance of the forest for the State of Wisconsin is very great, and the statement that "the forest industries have built every foot of railway and wagon road, nearly every town, school, and church, and cleared half of the improved land in north Wisconsin," is by no means an extravagant exaggeration.

In 1890, according to the census, the forest products at first hand, including lumber and all sawn timber; ties, hewn and round timber (not saw logs), poles, piling, posts, etc.; cooperage, furniture and wagon stock in the rough, and not including tan bark, pulp wood, and the immense quantities of timber used for firewood, fencing, and farm use and construction, represented the enormous sum of $40,400,000.

If to this is added only $10,000,000 as representing the value of the wood for home use, fuel, fencing, farm construction, etc., the products of the forest at first hand equal in value one third of the products of agriculture. And to these alone they are really comparable, since in most

manufactures large quantities of material appear repeatedly, often with slight or no modifications, as output of the same manufacture, as when a piece of costly sheet metal is first credited to the rolling mill, then to the tank or boiler maker, who merely cuts and rivets it into shape, and finally, without any modification at all, reappears as part of a distilling outfit or steam machinery, and thus the same highly manufactured article appears three separate times as items of the iron industry.

The sawmilling industry of the State alone represents a capital of about $84,000,000, or equal to more than one-eighth of the total valuation of taxable property of the State. The same industry pays a tax of $681,000, a sum equal to half the entire State taxes. It pays $3,000,000 for running expenses aside from wages, more than $15,000,000 for wages and contracts for bringing the raw material to the mill, besides expending nearly $1,000,000 for the maintenance of teams.

Besides these establishments, active in the mere exploitation of the woods, there are planing and pulp mills, furniture, cooperage, carriage, and car shops, the value of whose finished products in wooden materials amount to over $25,000,000 per year. The greater part of these is directly dependent for continuance on the forest supplies of the State.

FORESTS AND WATER FLOW.

The value of the forests in tempering the rigors of a northern continental climate and in maintaining a more uniform water flow by regulating drainage conditions can not here be considered; suffice it to say that the Fox River is failing, that the "June freshets," formerly a regular phenomenon of all the driving streams of this area, no longer occur, that hundreds of small swamps have become fields and meadows without a foot of ditching, and that miles of corduroy roads and roadways paved with poles and logs remain as unused relics, reminders of a moister state of things.

FUTURE OF SUPPLIES AND MILLING.

What the future will do for these important forests is difficult to say. That the pine forests are fast disappearing, that the hardwoods are being cut and their productive area reduced, is evident to everyone.

A closer examination shows that the hemlock growth can not be depended upon to continue itself by unaided natural reproduction. It has failed to reproduce for a long time. It also appears that the hardwoods, though perfectly able under normal conditions to hold their own and continue as forests, have not done so; that, especially on all lighter soils, the burned over lands are covered with runty, unpromising remnants, unable to keep out weeds and grass from the soil, injured by fire, and scarcely able to maintain the semblance of a woodland.

That pine, especially white pine, is perfectly capable not only to continue as forest, but also to reclothe old burned-over slashings on all kinds of soil, is amply proven by the numerous extensive young groves which may be seen, especially about Shawano, Grand Rapids, Black River Falls, and along the Wisconsin and Chippewa, and which occur in every county of north Wisconsin, probably aggregating not less than 200,000 acres. But it is equally certain that the great mass of pine slashings have remained and will continue to remain barren wastes, and that of the 8,000,000 acres of cut-over lands in north Wisconsin not one-tenth is stocked with growing timber. And even the swamp woods have no future, for it is here, among the tall marsh grass and masses of dead poles, that most of the fires start.

WHAT IS LOST TO THE STATE.

In this way an area now measuring about 8,000,000 acres and rapidly increasing in extent remains unproductive. Counting only 20 cubic feet, or 100 feet B. M., as the annual growth per acre on lands entirely without any care save protection against fire, the State of Wisconsin loses annually by this condition of things 800,000,000 feet B. M. of marketable saw timber; nor is this all, for even with primitive management this amount could largely be increased.

RÉSUMÉ OF CONDITIONS.

We have, then, briefly, the following state of affairs: Of the 18,500,000 acres under consideration not more than 7 per cent are under cultivation; the balance is forest, brush, swamps, or

waste. About 8,000,000 acres are cut over and practically exhausted for the present. Of available timber supplies a round 30,000,000,000 feet B. M. of coniferous material and some 14,000,000,000 feet of hardwoods, besides 100,000,000 cords of cordwood, are to be found on the 9,000,000 acres remaining.

The present consumption of saw timber alone may be set down as over 3,000,000,000 feet, not including railroad ties, pulp wood, posts, poles, and other bolt-size material, while the cut of coniferous material alone for the year 1897 may be placed at 2,500,000,000 feet B. M. The wood consumption altogether equals in value one-third the products of agriculture in the State. The lumber and wood-working industries relying upon this crop represent a capital of over $100,000,000, the lumber mills alone paying half the State taxes, and in wages and running expenses over $25,000,000. Not less than 20,000,000,000 feet of pine timber have been wasted by fires since lumbering began, about sixty years ago. The detrimental influence of forest destruction on waterflow of rivers is unmistakable.

As to the condition of the forest and cut over lands, it may be stated that there are no entire townships which remain unculled and in virgin condition. Of the 8,000,000 acres of cut-over land not one-tenth is stocked with growing timber, and this whole acreage has become unproductive. About 500,000 acres comprise the really promising young pine growths in parcels of any extent. While pine reproduces wherever fire does not prevent, the great mass of pine slashings have remained and will continue to remain barren wastes under the present policies.

WASTE LAND AND AGRICULTURE.

The injunction that this land is needed for agriculture, that it soon will all be settled, and that even the sandy soils produce potatoes and are profitably farmed by improved methods may well be answered by a concrete case: The old settled counties of Waushara, Adams, and Marinette have an aggregate area of 1,144,000 acres, their improved land amounts to 340,000 acres, leaving fully 70 per cent, or 804,000 acres, in brush and waste lands. In 1895 these counties supported wood industries whose products amounted to the pitiful sum of $13,000, and probably the material for these was imported, instead of having 80,000,000 feet of pine to sell, which, under simple methods of care, might have been derived from these brush and waste lands.

How soon the 17,000,000 acres of wild land in northern Wisconsin will be settled and improved no one can tell. The likelihood is that at least 10,000,000 acres, and among these much of the best lands, will remain unproductive brush land for fifty years to come.

Remedies.—What advantage it is to the county and State to have unproductive sand lands settled by poor and ignorant people and support farms "without barns" can not here be discussed. In the same way it is not here contemplated to enter into the question of communal property, i. e., whether it might not be well for a county, which can get land for the mere taking, to hold a few townships as county forest, and have these county forests at least defray the county expenses, giving at the same time work to many people.

What can be done to save the enormous loss to the State is clear—the land must be restocked and young timber must be given a chance to grow. What the fire has done to the pine supply is apparent from the conservative figures of original stand of pine.

This same work of destruction continues during this very fall (1897); many hundreds of acres of young sapling pine were ruined by fire, and it will require many years before the opening up of settlements and roads suffices to suppress the fire fiend. From this it is clear, and the fact is fully conceded by all persons conversant with the conditions of these woods, that the first and most important step in the right direction consists in the proper organization of an efficient fire police.

That a diversity of opinion as to the methods and even the possibility of suppressing the fires should exist is but natural. To most people the entire subject is foreign, the problem too large; to many even well-informed and experienced men the forest fire is an enormous affair, a calamity which man is entirely unable to combat. Nevertheless, the best informed men, nearly all woodsmen ("cruisers" and loggers), whose opinions were sought in this connection expressed themselves in favor of such a policy and certain of good results. The beginning of a forest-fire protection by the State is laid, but it requires further organization to be successful.

Without enlarging on this important subject, it may be of interest to point out a few fundamental facts which may help to shape a policy:

(1) All fires have a small beginning. The Peshtigo fire, by far the most terrific ever experienced in Wisconsin, was known to be burning and gathering headway for fully two weeks before it broke out in the final and then perfectly unmanageable form. The Phillips fire was heard and the smoke seen and felt in the town for days before it reached the village and converted it into ruins.

(2) All fires stop of their own accord after they have run for but a moderate distance, evidently finding obstacles which gradually reduce their power. The Peshtigo fire did not involve the fourth part of Marinette, the Phillips fire not a fourth of Price County, and a most intense fire in northern Chippewa, which when at its best sent firebrands across a lake over half a mile wide, did not keep on running, but stopped without going much, if at all, beyond the county line.

(3) The majority of fires are small fires. When the "whole country is on fire," it is not one fire, but hundreds of separate fires, all or nearly all of which have had their origin in carelessness.

(4) It is carelessness and not malice, and it is more carelessness of letting fires go than of starting them, which has resulted in the enormous losses mentioned before.

(5) Forest fires are both prevented and fought successfully in the wild forests of India, as well as in all parts of Europe, in localities where hundreds of acres of the young sapling pine with their fine and largely dead and dried-up branches (along the lower part of the stem) stand so thick that it is almost impossible to pass through, and where, in addition, poverty and chagrin among a dense population living close to the confines of the woods furnish willful and malicious incendiaries. To the greater part of opponents of a determined effort to cope with the problem, it may also be pointed out that for this country experience is as yet almost entirely wanting; that in New York State and in Maine the fire police has done well; that it is impossible for anyone to say at present just how successful the fire police of north Wisconsin could be. The success depends, of course, upon methods and organization, measures and men.

Reforestation.—What may be done to restock the land will vary from place to place, according as the land is well under way to reclothe itself, or is a bare waste, or is a tangle of débris or covered with worthless thickets of fire-damaged woods. This work may be done at once or by piecemeal, it may be done thoroughly or roughly, it may assist nature to a small or large degree, and any detailed directions are beyond the scope of this report.

To those who are frightened at the mere idea of planting forests, and who scorn European methods as impracticable in this country, it may be of interest to know that in the government forests of Saxony, which from 400,000 acres yield an annual net revenue of $1,900,000 continuously, and where forests are largely planted with nursery stock, the sylvicultural work of planting, sowing, etc., all told, amounts on an average for the entire woods to 10 cents per acre, and involves only 6 per cent of the total expenses, all logging operations included.

Whether similar efforts will pay here as long as the land is held by private owners whose fortunes are only of to-day, and whose heirs will prefer to parcel the land out to inexperienced settlers, can not here be considered. The experience abroad and also in this country indicates that the State must at least undertake the most difficult and unprofitable parts, and that the greatest good to the greatest number lies in State ownership of forests. New York waited a long time to see private owners manage its woods rationally, but has found itself compelled at last to buy the land and to establish a forest organization to keep its mountains from being converted into desert brush lands and its streams from being alternately dry branches and mud torrents.

THE NAVAL STORE INDUSTRY.[1]

The most important industry in the United States concerned in the utilization of by-products from the forest is the tanbark industry, which was at great length canvassed and discussed in volume 3, Reports on Forestry. Next to it in importance stands the turpentine or naval store industry, which is practically confined to the pineries of the Southern States within a belt of about 100 miles in width along the Atlantic and Gulf coasts from North Carolina to Louisiana.

The importance of this latter industry is found not only in the value of its products, namely, nearly $10,000,000 worth per year, furnishing the bulk of the naval stores used in all the world,

[1] Reprinted mostly from Report of the Chief of Division of Forestry for 1892.

FIG. 1.—CHIPPING THE LONGLEAF PINE.

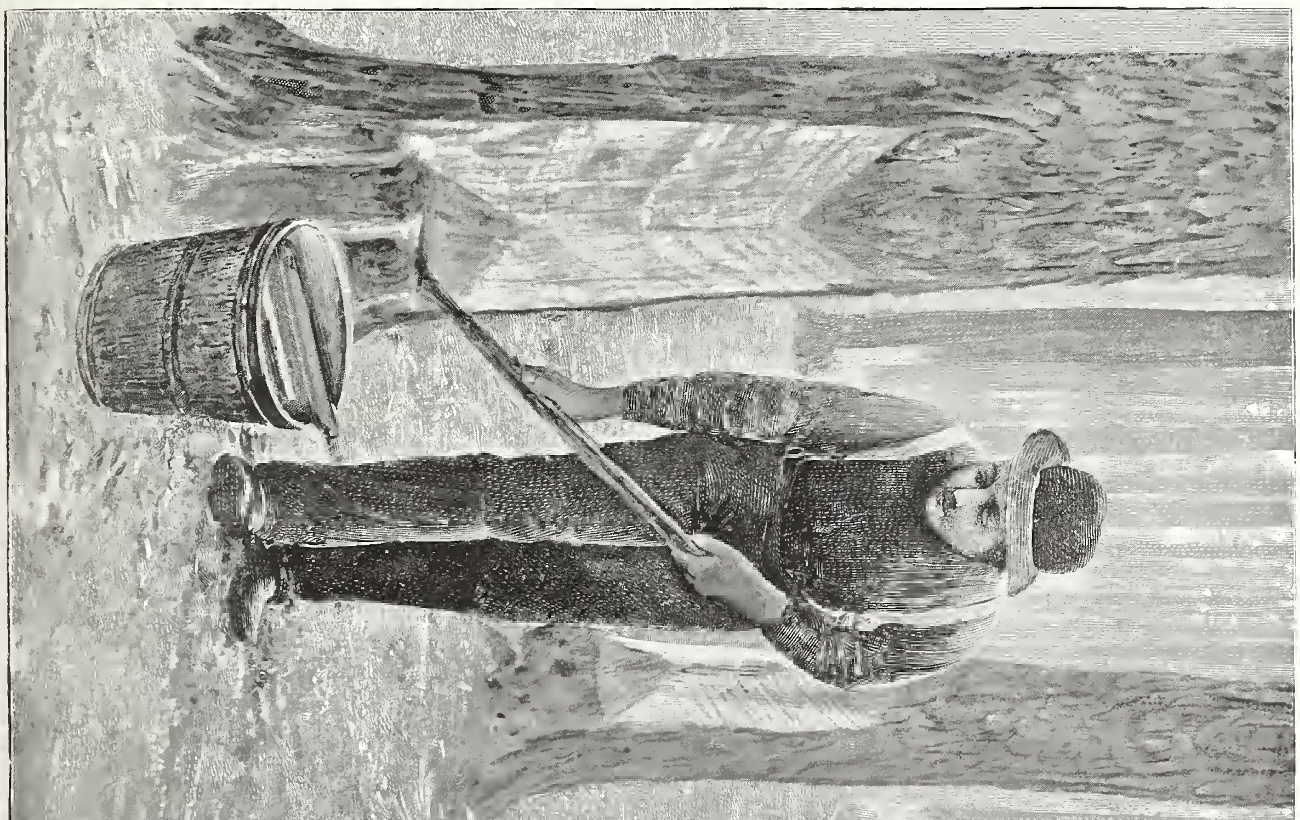


FIG. 2.—DIPPING THE CRUDE RESIN.

but also in the indirect influence which this industry exerts on the condition and future of one of our richest forest resources.

Owing to the wasteful and careless manner in which this industry is carried on and the disastrous conflagrations that follow in its train, which destroy thousands of acres of the most valuable timber every year, while the margin of profit to the turpentine gatherer is comparatively small, this industry may be considered the most unprofitable to the nation at large in spite of the large aggregate value of its products. This is not so by necessity, but due to faulty methods. The object of this discussion is to create a more general interest in the industry, give information regarding its methods, show its defects, and pave the way toward improvement and more rational procedure.

One of the most important results of the investigations of the Division of Forestry was the establishment of the fact that the bleeding of the Southern pines for the purpose of gathering naval stores does not, as has been generally maintained, affect the quality of their timber. Even the claim that tapped or bled trees lose their durability does not find any support in the chemical analyses made, which seem to prove that there is no change in the condition or chemical constitution of the heartwood due to bleeding; that the turpentine collected must come from the sap, where alone it is found in a condition permitting it to flow. Nor is there any physiological reason for assuming any change.

But while there is no deterioration of the timber due to the process of bleeding, it can be said with truth that there is no more destructive agency at work in the longleaf pineries of the South than the turpentine industry, and that without necessity. The damage and destruction do not result directly, although by the boxing of immature trees a considerable loss to the future is involved, and by the crude boxing much of the most valuable part of the tree is needlessly wasted; but often indirectly from fires, which annually sweep the turpentine orchards and destroy millions of feet of valuable timber, the resin collected on the scars of the trees rendering them highly inflammable. The trees which are not killed by the fire are soon destroyed by bark beetles and pine borers, which find a breeding place in the trees which, after the injury by fire, are blown down by the wind. "Hence," says Dr. Mohr, "the forests invaded by the turpentine industry present in five or six years after they are abandoned a picture of ruin and desolation painful to behold, and in view of the destruction of the seedlings and younger growth season after season all hope for the restoration of the forest is excluded."

It appears from the report of Dr. Mohr, agent of this division, that in 1890 over 2,000,000 acres of pine forest which were in orchard must have been exposed to this danger, and that every year adds between 600,000 and 800,000 acres of new orchard.

PRODUCTS OF THE TURPENTINE INDUSTRY.

Naval stores.—Under the name of naval stores are comprised all the resinous products and their derivatives that are gathered from coniferous trees. The name comes probably from the fact that the bulk of these products is or was used in the economy of ship construction and ship management, although now, with iron as a substitute for wood in shipbuilding, other industries may consume perhaps a larger portion. These products are:

(1) *Resin or crude turpentine.*—This is the crude material obtained by "tapping" or "bleeding" the trees, a mixture of resinous material and oil of turpentine, in which the resins are partly dissolved, partly suspended. According to the species from which it is obtained, the consistency of the resin varies, depending upon the relative proportion of hard resin particles and oil; the more oil, the more liquid is the resin.

The "fine" turpentine or resin, which comes from larch and fir or balsam trees, is semiliquid, more or less transparent and clear, and remains clear on exposure to the air. The "common" turpentine, which is furnished by the other trees tapped for it, is usually not at all transparent or clear, but is semiliquid or hard, the fluidity being lost by evaporation of the oil on exposure.

Most resins are yellow or brown in color, darkening on exposure; most of them possess a characteristic odor and taste; they have a specific weight of nearly 1, and when hard melt readily at low temperatures. They are not soluble in water, but readily so in alcohol, ether, or oil of turpentine; they are free from nitrogen, poor in oxygen, and rich in carbon, and of somewhat acid reaction. With alkalies the so-called resin soap is formed.

The best grades of turpentine are usually obtained (not necessarily so) in the product of the first year, known as "virgin dip" or "soft white gum;" in the following years it becomes "yellow dip," being darker colored and less liquid every year, while "scrape" or "hard turpentine" is the product hardened on the tree and scraped off. By distillation of the crude resin are obtained the important resinous products of trade.

(2) *Spirits of turpentine or oil of turpentine.*—This is the liquid distillate from the crude resin. When pure, it is

a mixture of hydrocarbons of the formula $C_{10}H_{16}$; but the impure product from the still contains also other hydrocarbons and acids. To rectify it, it is mixed with limewater and again distilled; yet, according to the source from which derived, the oil of turpentine possesses different qualities. Freshly prepared oil of turpentine. especially that from virgin trees worked for the first time, is colorless, tasteless, a thin fluid, of peculiar smell, of low specific weight (0.855–0.875), and its boiling point at 300–340° F. Most of the oils of turpentine of the trade polarize light to the left, but the American oil polarizes it to the right, and may thereby be recognized.

The oil evaporates very readily in ordinary temperature, and by oxidation thickens until hard, becomes yellow, and shows sour reaction. It burns with a strongly sooty flame; it is insoluble in water, but soluble in alcohol. It is a good solvent for many resins, wax, fats, caoutchouc, sulphur, and phosphorus. In the arts it is used mainly for the preparation of varnishes, in paints, and in the rubber industry. It is also used for illuminating purposes as pine oil, or mixed with alcohol as camphene, and under other names. It has a wide use in medicine internally and externally. It is often used in the adulteration or imitation of various essential oils.

(3) *Rosin or colophony.*—This is the residue remaining from the distillation of the crude turpentine or resin. According to the nature of the crude turpentine, which depends on the number of seasons the tree has been worked it shows different properties. It is either perfectly transparent, translucent, or almost opaque; in color, from pale yellow, golden or reddish yellow, through all shades to deep dark brown, almost black; and of different degrees of hardness; some soft enough to take the impression of a finger nail, and some so hard that only iron will make an impression.

The hard colophony or rosin is almost without smell or taste, of glassy gloss, very brittle, easily powdered. It becomes soft at about 176° F. and melts between 194° and 212° F. It is soluble in the same solvents as the crude resin; its specific weight is 1.07. Rosin is used in the manufacture of varnish, sealing wax, putty, soap, paper, etc.

In the American market the following grades are distinguished: WG—window glass; WW—water white, the lightest colored grade, obtained from virgin dippings and under special care at the distillery; N—extra pale; M—pale; K—low pale; I—good No. 1; H—No. 1; F—good No. 2; E—No. 2; D—good strain; C—strain; B—common strain; A—black.

By dry distillation of the rosin are obtained the following three products:

(*a*) Light rosin oil, which is used in the fabrication of varnishes.

(*b*) Heavy rosin oil, which is used in the manufacture of printers' ink, machine oil, axle grease, etc.

These oils, known in commerce as pale oil, pine oil, ink oil, etc., are of a light reddish or brown color, more or less fluorescent, with a specific gravity of 0.98 to 1; of slight odor but characteristic taste. The distillation is carried on at a dull, red heat, yielding about 85 per cent of rosin oil. They are composed of a mixture of several hydrocarbons of indefinite nature (colophene, heptin, etc.), and contain from 0 to over 15 per cent of resinous acids. They are insoluble in water, slightly so in alcohol, can not be saponified, but form unstable compounds with slaked lime and other bases. The rosin grease made by stirring slaked lime finely suspended in water is an excellent lubricant, adapted especially for metal bearings in machinery and wagons. Mixed with sweet oil, rape oil, or the denser mineral oils, it is used for the preparation of lubricating oils. These oils are also used in the manufacture of varnish, in the preparation of cheap paints used to cover metal, roofs, etc.

(*c*) *Common pitch.*—This is the residue from the dry distillation of rosin; a glossy, black, brittle body, which is used in the manufacture of the common ship-chandlers' pitch, used for calking of vessels, shoemakers' pitch, and black pigments. Pitch is also obtained by boiling tar down until it has lost about one-third or more of its weight. The navy pitch of commerce has more or less rosin of lowest grades added to it. It commands a price of about $1.50 per barrel.

(4) *Brewers' pitch.*—This is used for pitching beer kegs and barrels, and is obtained when the distillation of the crude turpentine is stopped, before all the oil has been distilled. It therefore contains a certain quantity of oil of turpentine; if too much, the pitch foams when melted and imparts a disagreeable, sharp taste to the beer, while with too little oil the pitch becomes brittle and does not adhere to the barrel. The best quality of this product is obtained from the larch, and is produced mostly in Tyrol, but there is quite an amount of brewers' pitch made in the Southern pineries.

(5) *Tar.*—This is not exactly a by-product of the turpentine orchard, but is mostly a product of destructive distillation of the wood itself. Most of the tar in the United States is made in North Carolina, where the industry has been largely carried on from earliest colonial times. In other parts of the Southern coast pine belt it is only produced for home consumption. Perfectly dry wood of the longleaf pine—dead limbs and trunks perfectly seasoned on the stump, from which the sapwood has rotted—are cut into suitable billets, piled into a conical stack in a circular pit lined with clay, the center communicating by a depressed channel with a receptacle—a hole in the ground—at a distance of 3 or 4 feet from the pile. The pile is covered with sod and earth, and otherwise treated and managed like a charcoal pit, being fired from apertures at the base, giving only enough draft to maintain slow smoldering combustion. After the ninth or tenth day the flow of tar begins, and continues for several weeks. It is dipped from the pit into barrels of 320 pounds net, standard weight, mostly made by the tar burner himself from the same pine. From one cord of dry "fat" wood or "lightwood" from 40 to 50 gallons of tar are obtained.

There is but little profit in the business, except that it employs labor in remote districts at a season (winter) when there is but little else to do. The price of tar, at present quoted as low as $1.05 per barrel at Wilmington, N. C., has been depressed, especially since considerable quantities of tar are produced incidentally in the destructive distillation of wood in iron retorts for charcoal purposes.

(6) *Oil of tar.*—This is obtained by distillation of the tar. It is a complex mixture of hydrocarbons with some wood alcohol and a small quantity of creosote, often more or less covered by empyreumatic substances, with a density of 0.841 to 0.877. It is used as an insecticide and for various external applications in domestic and veterinary practice.

SOURCES OF SUPPLY.

Naval stores are being produced on a commercial scale mainly in Austria, France, on the island of Corsica, in Spain, Portugal, Galicia, Russia, and the United States. The largest amount of European turpentine comes from the black pine (*Pinus laricio*) and the maritime pine (*Pinus maritima*). The first of the two, which yields the largest amount, is tapped especially in Lower Austria, France, and Corsica. The latter, which does not furnish much resin, is tapped especially in France, between Bayonne and Bordeaux, where about one and a half million acres are covered with it; also in Spain, Portugal, and on the North African coast. In Germany, especially in the Black Forest, the Norway spruce is tapped, but not to any great extent. In Southern Italy and the Italian Alps the larch furnishes resin of excellent quality, although small quantities per tree and year, which is known in trade as Venetian turpentine. Occasionally, and especially in Galicia, Russia, the Scotch pine and fir are tapped; the turpentine from the latter species which is bled in Alsace is known as "Strasburg" turpentine. The Hungarian turpentine, so called, comes from the Carpathian Mountains and is derived from the pine known as *Pinus pumilio*.

In the United States a considerable amount of naval stores used to be collected in colonial times from the pitch pine of the North Atlantic States (*Pinus rigida*); but this species has been so far exhausted and forest conditions so changed that this industry is now practically extinct in the North and the business of turpentine gathering is confined entirely to the South. There are three pines in the South which yield resinous products abundantly, the longleaf pine (*Pinus palustris*), the loblolly (*Pinus tæda*), and the Cuban pine (*Pinus heterophylla*). The botanical features, their distribution, value as timber trees, etc., may be found in an earlier part of this report.

The loblolly and Cuban pine yield a more fluid resin, rich in volatile oil, which when distilled leaves a smaller proportion of the solid rosin. The resin of these trees runs so rapidly that it is exhausted during the first season, and hence it is not considered profitable to work them, although they are always tapped where they are found intermixed with the longleaf pine. It is, however, possible, nay probable, that with more careful methods, differing from those now employed, these two species may be made more productive and that the compact forests of the loblolly in Arkansas, Louisiana, and Texas may still become valuable sources of naval stores as well as the Cuban pine forests of Florida.

At present the longleaf pine furnishes the bulk of naval stores, not only for the United States, but for the whole world, the production of France and Austria, the only other producers of naval stores, furnishing hardly one-tenth of the total production.

HISTORICAL NOTES AND STATISTICS.

The first production of naval stores from longleaf pine took place in North Carolina. The tapping of the trees for their resin and the production of pitch and tar was resorted to by the earliest settlers as a source of income, and during the later colonial times it had risen to a profitable industry, which furnished the largest part of the exports of the colony. In the three years—1768 to 1770—88,111 barrels of crude turpentine, 20,646 barrels of pitch, and 88,366 barrels of tar were on the average annually exported to the mother country, representing a value of $215,000 in our present currency. In its infancy the manufacture of naval stores was confined to the district between Tar and Cape Fear rivers, with Wilmington and Newbern for shipping ports. Most of the turpentine or crude resin was shipped to England. Later the distillation of spirits of turpentine was carried on to a small extent in Northern cities as well as in North Carolina. Up to the year 1844 fully one-half of the crude product was subjected to distillation in the latter State, the process being effected in clumsy iron retorts. The introduction of the copper still in 1834 led to a largely increased yield of volatile oil, and this industry received a strong impetus. The number of stills at the ports was increased, and the production grew yet further shortly afterwards, caused by the new demand for spirits of turpentine in the manufacture of india-rubber goods, and turpentine orcharding was rapidly extended to the south and west of its original limit. As early as 1832 rectified spirits of turpentine was used for an illuminator, and for that purpose came into general use in 1842, either alone in the rectified state or mixed with a certain quantity of strong alcohol, under the names of camphene and burning fluid, furnishing the cheapest light until replaced by the products of petroleum. The large consumption of spirits of turpentine in this way caused such an increase in its production that the residuary product, rosin,

was largely in excess of the demand, leading to a great depreciation of this article. The consequent reduction of the profits of the business caused the transfer of the still from the place of shipment to the source of the raw material—the forest. From that time (1844) dates the great progress made in the expansion of this industry to the virgin forests farther south, and the turpentine stills increased rapidly in number in South Carolina, Georgia, Florida, and the eastern Gulf States.

During the war of secession, when the production in the South was stopped, the turpentine industry of France received an impetus, and that country supplied as best she could the deficiency. Prices went up to five or six times their former range, namely, \$25 to \$30 per 100 pounds for spirits, and \$9 to \$10 for pale yellow grades of rosin, \$4 to \$5 for inferior grades. These prices instigated improvement of methods, such as the Hugues system, described further on, and more careful treatment of the crop.

With the close of the war the industry revived in the United States, though the demand for turpentine was not as great as formerly, petroleum products of various kinds having been found to take the place of the product of the pine for many purposes. With the general extension of arts and manufactures, however, both in this country and abroad, and new application of the products, there has been an increasing demand both for spirits of turpentine and resin, the exports of these alone in the year 1891 being \$8,135,339 in value.

The following table of exports of naval stores has been compiled with great care by Charles Mohr from the reports of the boards of trade, the press reports published in the several ports of export, and partly from private information. The amounts given are not claimed to comprise the total annual production, but will fairly represent the bulk of production in each year for the ten or twelve years included.

Table of exports of naval stores from the markets of principal centers of production during the period 1880 to 1890.

Year.	North Carolina (Wilmington).		South Carolina (Charleston).		Georgia (Savannah).		Alabama (Mobile).	
	Spirits turpentine.	Resin.	Spirits turpentine.	Resin.	Spirits turpentine.	Resin.	Spirits turpentine.	Resin.
	Casks.	*Barrels.*	*Casks.*	*Barrels.*	*Casks.*	*Barrels.*	*Casks.*	*Barrels.*
1879–80	125, 585	663, 967	60, 000	259. 940	46, 321	221, 421	25, 209	158, 482
1880–81	90, 000	450, 000	51, 386	231, 417	54, 703	282, 386	25, 224	170, 616
1881–82	88, 376	425, 925	69, 027	258, 446	77, 059	309, 834	30, 937	172, 438
1882–83	87, 050	483, 432	65, 914	285, 446	116, 127	430, 548	43, 870	200, 125
1883–84	78, 978	434, 367	64, 207	264, 049	129, 835	559, 625	41, 804	210, 512
1884–85	71, 145	310, 808	44, 126	218, 979	121, 028	401, 998	41, 713	200, 688
1885–86	63, 580	324, 942	40, 375	170, 066	106, 925	424, 490	38, 733	175, 817
1886–87	71, 912	381, 335	52, 549	171, 145	146, 925	566, 932	40, 149	182, 955
1887–88	63, 473	246, 516	40, 253	181, 886	168, 834	654, 286	28, 725	132, 055
1888–89	61, 628	351, 827	43, 127	149, 348	159, 931	577, 990	23, 927	106, 129
1889–90	70, 289	385, 523	49, 232	217, 865	181, 542	716, 658	21, 029	93, 906

Exports of tar and crude turpentine from Wilmington, N. C.

Year.	Tar.	Crude turpentine.	Year.	Tar.	Crude turpentine.
	Barrels.	*Barrels.*		*Barrels.*	*Barrels.*
1881–82	56, 113	2, 323	1886–87	68, 143	24, 662
1882–83	75, 544	3, 188	1887–88	63, 163	21, 572
1883–84	85, 230	31, 966	1888–89	68, 856	18, 171
1884–85	70, 530	45, 966	1889–90	71, 949	19, 082
1885–86	69, 195	35, 290			

Adding to the above records the production reported from Mississippi and Louisiana, which is said to have averaged, for the last two years, 75,000 barrels of resin and 15,000 casks of spirits, being marketed in New Orleans, we may estimate the total production at present (1892) as round:

340,000 casks spirits of turpentine, or 17,000,000 gallons, at 35 cents	\$6, 000, 000
1,490,000 barrels (240 pounds net)[1] resin of grades W W to C, or 357,600,000 pounds, at \$1.80 average price per barrel or per 280 pounds gross	2, 682, 000
	8, 682, 000

[1] Lately the weight per barrel has been greatly increased, so that it now varies from 350 to 450 pounds net.

From the same reports we quote the following data regarding the development of the industry in the different States (no regular returns from any district are obtainable regarding the annual production of naval stores derived from the longleaf pine previous to 1870):

GROWTH OF THE TURPENTINE INDUSTRY IN THE STATES.

North Carolina.—This State, the oldest site of production, took the lead in this industry up to the census year 1880. In the census of 1850 the value of these products of that year is stated at $2,476,225, and in the census of 1860 at $996,902. The production in 1870 of 75,990 casks of spirits of turpentine (equal to 37,995,000 gallons) and 456,131,388 barrels of resin valued at $2,337,300, increased in the business year ending 1880 to 125,585 casks of spirits of turpentine and 663,967 barrels of resin of a value of $3,146,388, showing an increase of 65 per cent in spirits of turpentine and of 45 per cent in resin. From that year to the present a gradual decline has taken place, which, in the year 1888–89, amounted to 50 per cent in spirits and 48 per cent in the resin. The exports in that year reached a value of only $1,170,932. This decline is clearly due to the exhaustion of the natural resources. During the period of ten years, from 1879–80, 1889–90, $2,114,483 worth of spirits of turpentine and resin, on the average, were each year exported. From the returns available it appears that nearly all the tar and crude turpentine shipped to domestic and foreign ports is produced in North Carolina. The export of these stores from Wilmington in 1889–90 amounted to 71,949 barrels of tar and 19,082 of crude turpentine, at a value of not less than $253,000.

South Carolina.—By the census of 1850, the naval stores produced in that year were valued at $235,836, and in the census of 1860 their value is stated at $205,249.[1] According to the returns made to the census in 1870, 31,647 casks of spirits of turpentine and 115,945 barrels of resin were produced at a value of $779,077, rising in 1880 to 60,000 casks of spirits and 259,940 barrels of resin, at a value of $1,491,853—an increase of nearly 100 per cent in spirits of turpentine and 124 per cent in resin. After a slight check in the succeeding year, the production shows for the next four years an increase of 10 per cent on the average annually over the production in 1880. With the year 1885 a decline took place; the production between that year and the end of 1890 varied between 39,651 casks of spirits of turpentine and 218,962 barrels of resin and 49,430 casks and 217,865 barrels. The value of the products in 1888–89 amounted to $968,761. The average price of resin reached in that year the lowest figure of $1 a barrel. The production of the same year shows a decline of 28 per cent in spirits of turpentine and 40 per cent in resin compared with the production of 1880.

Georgia.—In 1850 the naval stores produced reached a value of $55,086, and by the statements of the census of 1870, 3,208 casks of spirits of turpentine and 13,840 barrels of resin, valued at $95,970, had been produced in Georgia during that year. In the course of the following ten years the naval store industry made great progress, resulting in 1880 in the export from Savannah of 46,321 casks spirits of turpentine and 221,421 barrels resin, at a value of $1,202,555, followed by a steady increase which, in 1884, exceeded the production of North Carolina during its palmiest days, and has been constantly progressing to the present day. In the year closing 1889, the exports from Savannah reached 159,931 casks spirits of turpentine and 577,990 barrels of resin, valued at $3,616,680—an increase of 227 per cent in spirits turpentine and 161 per cent in resin over the production of 1880. To-day this port is the greatest market for these stores in the world.

Alabama.—According to the statements in the census of 1850, the naval stores produced in Alabama represented a value of $17,800, which in 1860 declined to $13,575, and in 1870, by the production of 8,200 casks spirits of turpentine and 53,175 barrels resin, reached a value of $280,203. In 1873 the receipts in the market of Mobile had increased fully 50 per cent over those of the previous year, amounting to from 15,000 to 20,000 casks spirits turpentine and from 75,000 to 100,000 barrels resin, besides 1,000 barrels tar and pitch, of a value estimated at $750,000. In 1875 the receipts reached a value of $1,200,000, which in the year 1879–80 was reduced to $739,000. In the year 1883 the production had increased again to 43,870 casks spirits turpentine and 200,125 barrels resin, with but slight fluctuations to the end of 1887, indicating an increase of 59 per cent in spirits turpentine and 21 per cent in resin over the production in 1880.

With the beginning of 1888 a decline set in. During that year the receipts at Mobile were reduced to 28,725 casks and 132,055 barrels, valued at $635,643, and still further, in 1888–89, to 23,927 casks and 106,129 barrels, of a value of $556,399. The receipts of spirits turpentine fell that year 47 per cent, and of resin nearly 49 per cent, below those of 1883, the year of greatest production, and the returns of the following years show still greater reductions. This decline is to be ascribed to the exhaustion of the forests along the lines of communication by water and by rail, and the consequent reduction in profits caused by the increased expense of transportation of the products from the still to the shipping points, ports, or inland markets. The receipts at Mobile include all of these stores produced in eastern Mississippi.

Other States.—In Mississippi and Louisiana this industry has not as yet reached large dimensions, while it is not known that turpentine orcharding is carried on in the magnificent pineries of Texas. The production along the New Orleans and Northeastern Railroad is reported to have averaged for the last two years 15,000 casks of spirits of turpentine and 75,000 barrels of resin.

PHYSIOLOGY OF RESINS.

All coniferous trees, with the exception of those of the genus *Taxus*, contain in their woody structure passages or pockets, filled with resin, known as resin ducts or resin vesicles. How and

[1] F. B. Hough's Report on Forestry to the Department of Agriculture, 1878, IXth, Vol. II, 333.

under what conditions exactly these ducts and vesicles arise, and how and why the resin forms, are matters still imperfectly understood. Resin passages begin to develop in the young seedling, and even during germination; resin forms in the growing bud, however, only during normal respiration and growth. It is, then, a product of the living plant, formed by and during its life functions in the living parts of the plant; yet, as far as we know, it is a product of decomposition, which, while perhaps not useless in the economy of the plant, seems to find no further use in the nutrition or growth of its organs.

Resin passages arise from the shrinking away from each other of the walls of neighboring rows of cells; an intercellular space is thus formed and gradually filled up with products of decomposition and secretion, which we call resin. The source of these secretions is also still more or less unexplained. In the first place it comes, no doubt, from a decomposition of the cellulose of the surrounding cell wall; then the starchy contents of the cells themselves may change into resin, and by oxidation of terpenes, essential oils, the surrounding cells with their contents are liquefied and resorbed, and in this way the resin duct becomes filled and enlarged from a mere intercellular passage to an irregular smaller or larger pocket or canal. The number, size, and arrangement of the resin ducts and vesicles differ with different species.

The Cupressus genus all have isolated cells containing resin; some have also ducts, the contents of which give the wood its peculiar odor, but these do not contain sufficient quantities to permit extraction except by distillation of the wood itself. One of the Thuya tribe (*Callitris quadrivalvis*), of Algiers, furnishes the white resin, known as sandarac; and the fruit of the juniper, rich in essential oil, is used in the preparation of gin, the flavor of which is due to the oil.

The wood of the firs (*Abies*) does not contain any resin ducts, only isolated resin cells and vesicles, which are found most amply in the bark, containing an oleoresin very rich in volatile oil, and hence very liquid. The wood of the spruces (*Picea*) contains few, rather narrow, longitudinal ducts, and wider lateral ducts strongly developed. The larch (*Larix*) contains resin ducts of very large diameter. The largest development of resin passages, however, occurs in the pines (*Pinus*), admitting extraction on a large commercial scale.

In these we find longitudinal resin ducts in greater or less abundance, according to the species, in all parts of the annual rings, more frequently, however, in the summer wood than in the spring wood; hence, in part, the darker coloration of the former. Those of the ducts which pass near a medullary ray form lateral extensions along the cells of the rays, by means of which the longitudinal ducts are more or less frequently connected. These lateral ducts extend into the bark, where sometimes considerable pockets of resin are formed; the longitudinal ducts are, however, the most important source of resin supply in the pine.

As we have seen, the production of resin takes place under the life functions of the tree in the living parts. Whether, and if so how, the resin wanders in the tree is not well known. Small amounts, no doubt, remain at the place where they were formed. Larger masses may change their place, following the law of gravity, although the observation that leaning trees are richest in resin on the under side does not necessarily predicate a wandering. The collection of resin in the hollows of trees (frost pits) of the larch may not be due to a wandering of the resin, but an emptying of broken ducts into the open spaces, in which the counterpressures otherwise existing are relieved.

The special investigations undertaken in the Division of Forestry, and recorded in Bulletin 8, and reproduced in a later part of this report, have shown that the quantitative distribution of resin throughout the tree, from top to bottom, follows no law, the larger amounts being as often found in the top or middle portions as in the butt-logs.

If the claim that the roots and base parts are richest in resin be a fact, this need not be due to a wandering of the resin, but to more abundant production in those parts. The belief that in trees bled for turpentine a change takes place in the distribution of resin was not sustained in the investigations. It was, however, found that the heartwood of old trees contains invariably more oleoresin than the sapwood, the largest amount relatively being found at the line where heart and sapwood join. This would indicate an infiltration of the heartwood with resin from the sapwood. Before, however, accepting such a conclusion, in which we would find it hard to explain mechanical difficulties in the wandering of the resin, it would be desirable to examine trees of different age and note the progress of resinification, and also to make further analyses on

absolutely fresh wood in which the sapwood is guarded against loss of resinous contents by evaporation and otherwise.

Of practical importance is the demonstration, furnished in these investigations, that the resin of the heartwood has lost its fluidity, being probably infiltrated into the cell wall, and therefore the tapping for turpentine does not involve the resin of the heartwood or produce any change in the same.

Concerning the conditions which encourage abundant resin production we are also in the dark. Trees standing side by side, and apparently under the same conditions, show widely different amounts of resin. In general it may be said that light and warmth are prime requisites for abundant resinification, hence this proceeds more rapidly in open groves than close plantations; abundant nourishment and energetic activity of life seem also advantageous to resin production, hence a strong, fresh, warm soil furnishes more resin than a thin and cold soil, trees with full crown and branches more than thin-foliaged and densely crowded trees with small crowns; warm and dry summers produce a richer flow than wet and cold ones.

METHODS OF WORKING TREES.

The methods of working trees for turpentine differ with the different species, as also in different countries According as the resinous contents are found mainly in the bark or in the sapwood or in the heartwood, we may discern various methods.

(1) Chipping: this method consists in making a scar or chip on the tree, which is annually enlarged, and gathering the liquid turpentine at the lower end of the chip or scar in recess (box) cut into the tree; or else, as in France, in vessels; or else by allowing the resin to dry and be scraped, as is done with the Norway spruce.

(2) Bore-holes are applied in the tapping of larch, where the turpentine is formed or collected in the heart.

(3) Opening the resin vesicles of the bark and gathering by hand is applied in the case of the balsam.

The yield of resin and turpentine depends upon various circumstances besides the species from which it is gathered, namely: (1) The dimensions of the tree; the larger the tree, of course, *ceteris paribus*, the larger the yield; the yield of trees of small diameter, 7 to 10 inches, may be from one-half to one-third of those of larger diameter. (2) The conditions of site; all elements which further large development of the crown, mainly open and sunny position, south or east exposure, will increase the yield. (3) The weather, and especially the temperature, during the time of gathering; the most favorable weather is changing temperature and humidity; long-continued heat and long-continued cold rains depress the yield, especially a cold spring predicts a poor crop; the flow of turpentine increases from spring to fall. (4) The duration of the bleeding process; in the first two or three years the yield is or ought to be smaller than in the following years. With the Austrian (black) pine the maximum yield seems to be reached in the trees of smaller diameter between the fourth and sixth years; in the trees with larger diameter, over 10 inches, between the seventh and ninth. Trees of these species on proper sites can be utilized for thirty years, but working becomes less profitable after six or eight years for the smaller and ten or twelve years for the larger sizes; the expense of working growing too costly, the foliage becoming thinner, and the yield smaller. (5) The aptitude and care of the workmen, which tells in the manner of making and enlarging the chips and of dipping and scraping.

PRINCIPLES TO BE OBSERVED IN TURPENTINE ORCHARDS.

The principles which should be observed in the chipping process, the one practiced on the largest scale, especially on pines, are as follows:

Size or age of trees to be tapped.—There is not sufficient experimental knowledge at hand to determine the most advantageous size of trees for tapping, either as far as greatest annual production of turpentine or safety to the life of the tree is concerned. The experiments on Austrian pine, recited further on, seem to show that trees above 10 inches in diameter yield much more than smaller trees, almost double the amount of resin, with a higher percentage of spirits of turpentine. It also stands to reason that the safety of the tree, where this is of moment, is better

assured in the larger tree. Generally speaking, the best time for plentiful production is neither near the beginning nor near the end of the life of the tree, but when it is in its most vigorous growth, and probably after it has attained its maximum annual height growth, for then its activity is concentrated upon the development of its interior and diameter development.

If the analyses referred to before exhibit the true amounts of resin formed in the part of the tree from which they are taken, and if our proposition be true that ordinarily resins do not wander in the tree but remain where they are formed, then we could, by analyses of cross sections, dividing them into periods and ascertaining the resin contents of each division, approximately determine the period of greatest production. In view of the great variation in resin contents, a very large number of analyses would be required to allow generalization. From those at hand it would appear that the time of greatest production falls for the longleaf pine between the seventieth and ninetieth years. Since, however, resin production appears to be a result of vigorous life functions, and since wood production depends upon the same conditions, we should rather seek a criterion for resin production in the relation of diameter to age $\frac{d}{a}$; that is to say, whenever the largest amount of wood is formed in a given time—whenever $\frac{d}{a}$ reaches its greatest value—then the largest amount of resin is presumably also formed. Investigations in this direction are still wanting.

Another consideration is that of the value of the tree after it has been bled. Since the wood which is formed after the bleeding either on or between the scars is of little value for sawmilling, no trees should be bled—unless they are otherwise unfit for lumber—that will not make good saw logs from the heartwood; that is to say, they should be at least 14 inches in diameter, so as to furnish a log of at least 8 inches at the small end. If the diameter were allowed to increase to at least 18 or 20 inches, probably the largest value both in resin and lumber might be attained.

In practice, various rules have found acceptance. In France 14 inches, which may be attained in thirty years, is considered a necessary diameter in order to endure continued tapping without injury to life; the lumber value of the maritime pine, being small, enters hardly into consideration. In Austria the tapping is begun with trees as low as 8 inches in diameter, but a diameter of at least 10 inches is preferred. With the spruce, 12 inches is considered a minimum size. In the United States, where no regard to consequences for the tree or lumber is had, the diameter at which a tree might be tapped is gauged by the amount of resin obtained in proportion to the labor expended. Until lately small diameters were avoided, but now any tree capable of carrying a bore is tapped and the ruin of the future of the industry prepared by this malpractice.

Size and number of scars and progress of chips.—Regard to the life of the tree and the length of time for which it is expected to produce, on one hand, and the rapidity with which the largest amount of resin can be extracted in the shortest time, on the other hand, determine the size and number of scars inflicted simultaneously. Although the resin itself is or seems to be of no particular use to the tree in its vital functions, by laying bare a part of the cambium and young wood a diminution of the flow of water to the crown, and of nutritive material downward, must be induced. As a result the foliage must suffer in proportion, and with it not only the life of the tree, but also the production of additional resin, which is produced in quantity only in vigorously growing trees with a luxuriant foliage. Hence both the life of the tree and the total yield of resin may be curtailed by too many and too large scarifications.

Since there is a relation between the amount of active foliage on each side of the tree and the activity in the cambium on the same side (one-sided crowns produce one-sided annulation), it stands to reason that a larger product can be obtained for a longer time by inflicting a number of smaller scars than by making a large scar on one side of the tree, which is bound to reduce the activity of the foliage on that side, and thereby the production of additional resin; not that the dripping itself increases the production of new resin, as has been sometimes thought, but new resin is formed every year in proportion to the activity of the foliage, and hence by impairing this activity the amount of new resin in the new wood is reduced.

As we have shown, the resin which the orchardist takes from the tree, in the longleaf pine, at least, comes alone from the sapwood, the heartwood being impregnated with nonfluid oleoresin and not contributing toward the flow. The resin tapped is not only that which was deposited in the sapwood in former years, but also that which is formed during the years of tapping by the growth of the tree; hence sufficient amount of active cambium and young wood should be left untouched to permit a plentiful supply of water from the ground and vigorous function of the

foliage, and the size of the one scar, or the sum total of all the scars, if several, should stand in a certain relation to the circumference or diameter of the tree.

For the size of the scar three dimensions are to be determined—breadth, depth, and height. Breadth and depth should be determined by the considerations just stated. As far as product is concerned there is nothing gained—at least in our pine—by cutting deeper than the sapwood, since the heart is inoperative. The breadth may be larger or smaller according to whether the tree is expected to yield resin for a long time or is to be depleted as fast as possible. In the former case the scar should not be wider than can conveniently callous over in a few years' rest, so as to permit new scars to be opened after the rest without any diminution, so to say, of conducting cell tissue. In the latter case, i. e., when the largest amount of resin is to be obtained in the quickest time, without reference to the life of the tree, only enough cambium need be spared to sustain the tree alive during the period which it takes to carry the chip advantageously to the greatest practical height. In this case, to be sure, only the resin already formed in the sapwood is being drained, no new additions coming from the growth during the years of tapping. The greater the breadth of the chip the greater, no doubt, the momentary discharge. The height of the chip, in the pines at least, should be determined by the following considerations: The resin drains from the longitudinal resin ducts which are cut through, by the law of gravity, until by the volatilization of the solvent oil of turpentine the hardened resin stops the flow; hence regard to plentiful production dictates as low a chip to begin with as is possible to collect from. A high chip at first and rapid chipping afterwards is a useless waste of good material, without any benefit, since the flow depends only upon the number of resin ducts cut through radially.

In practice the French have come nearest a rational size of the scar, not allowing it to be more than 4 to 5 inches wide and scarcely one-half an inch deep, beginning with a height of not more than 4 inches and progressing afterwards with the greatest care very gradually. With such chips it is possible to bleed the trees without detriment for their whole natural life. In Austria the size is extravagant, namely, widening to two-thirds of the circumference, although the height is at first started with only 2 inches. In the United States a waste of 10 inches is at once incurred by "cornering" the box, and the chip is made 12 to 14 inches wide without much reference to the life or size of the tree, and several chips are opened on larger trees.

Method of collecting the resin.—The pocket interest of the orchardist makes it desirable to have the largest amount of "dip"—that is, liquid resin—and the smallest amount of "scrape," or hardened resin scraped from the surface of the scar, for the former contains larger amounts of the more valuable oil which has been evaporated from the latter by exposure to the air, as the resin, in a thin layer, runs to the receptacle. It is therefore advantageous to reduce as much as possible the distance between the place at which the resin exudes and the receptacle and also to concentrate as much as possible into one channel the flow of resin.

The American practice, it will be seen, is entirely faulty in this respect, and the Austrian not much better, the French alone being rational.

Frequent collection from receptacles at the trees also reduces loss from evaporation. Cleanliness—keeping impurities, sand, chips of bark, and wood out of the receptacles—is reflected in the better grades of the product. Scraping should be done as rarely as possible, since it injures the tree, and after the resin is once hardened the loss of oil by exposure is only insignificant.

TURPENTINE ORCHARDING IN AMERICA.

The American practice of boxing and chipping is thus described by Dr. Charles Mohr, agent of the Division of Forestry:

In the establishment of a turpentine orchard and still two points must be considered, namely, (1) proper facilities of transportation to shipping points for the product, and (2) a sufficient supply of water for the condenser connected with the still. The copper stills generally in use have a capacity of about 800 gallons, or to carry a charge of 20 to 25 barrels of crude turpentine. For such a still to be charged twice in twenty-four hours during the working season not less than 4,000 acres of pine land, with a good average stand of timber, are required. This area is divided into twenty parcels, each of 10,000 "boxes," as the cavities are called, which are cut into the tree to serve as a receptacle of the exuding resin. Such a parcel is termed a "crop," constituting the allotment to one laborer for the task of chipping. The work in the turpentine orchard, as such a complex is called, is started in the earlier part of the winter, with the cutting of the boxes. Until some years past no trees were boxed of a diameter of less than 12 inches; of late, however, saplings scarcely over 8 inches in diameter are boxed. Trees of full growth

according to their circumference, receive from two to four boxes; so that the 10,000 boxes can be said to be distributed among 4,000 to 5,000 trees on an area of 200 acres.

The boxes are cut (see Pl. XXIX) from 8 to 12 inches above the base of the tree, 7 inches deep (*b–f*) and slanting from the outside to the interior with an angle of about 35°; they are 14 inches in greatest diameter (*d–e*) and 4 inches in greatest width (*b–c*) at the top, of a capacity of about 3 pints; the cut above this reservoir forms a gash of the same depth and 6 to 7 inches of greatest height (*a–b*). In the meantime the ground is laid bare around the tree for a distance of 2½ or 3 feet, and all combustible material loose on the ground is raked in heaps to be burned in order to protect the boxes against the danger of catching fire during the conflagrations which are so frequently started in the pine forests by design or carelessness. This work of raking around the trees is also done to give the chipper in the performance of his task a firmer foothold on the ground than could be obtained when covered with the slippery pine straw. The employment of fire for the protection of the turpentine orchard against the same destructive agency necessarily involves the total destruction of the smaller tree growth, and, left to spread without control beyond the proper limits, carries ruin to the adjoining forests, in many instances over areas many miles in extent. The tools used are illustrated on Pl. XXIX, and are described as follows: Fig. 1, chipper; fig. 2, pusher; fig. 3, open hacker; fig. 4, closed hacker; fig. 5, scraper; fig. 6, puller.

With the first days of approaching spring the turpentine begins to flow and "chipping" is begun, as the work of the scarification of the tree is termed, by which its surface above the box is laid bare just beyond the youngest layers of the wood, scarcely to a depth of an inch from the outside of the bark. To effect this first a strip 2 inches wide is removed, extending vertically from the corner of the box to the height of about 10 inches ("cornering"), and then the surface between these strips is laid open. The removal of the bark and outermost layers of the wood, the "chipping" or "hacking," is done with a peculiar tool, the "hacker" (Pl. II, figs. 3 and 4), a strong knife with a curved edge, fastened to the end of an iron handle bearing on its lower end an iron ball about 4 pounds in weight, in order to give increased momentum to the force of the stroke inflicted upon the tree, and thus to lighten the labor of chipping. As soon as the scarified surface ("chip") ceases to discharge turpentine freely, fresh incisions are made with the hacker. The hacking or chipping is repeated every week from March to October or middle of November, extending generally over thirty-two weeks, and the height of the chip is increased about 1½ to 2 inches every month. The resin accumulated in the boxes is removed to a barrel for transfer to the still by a flat, trowel-shaped dipper ("dipping"). In the first season, on the average, seven dippings are made (from six to eight). The 10,000 boxes yield at each dip about 40 barrels of dip or soft turpentine, or "soft gum," as it is called in Alabama, of 240 pounds net or 280 pounds gross weight. The flow is most copious during the hottest part of the season, July and August, diminishes with the advent of cooler weather, and ceases in October or November. As soon as the exudation is arrested and the crude resin begins to harden, it is carefully scraped from the chip and the boxes with a narrow, keen-edged scrape attached to a wooden handle ("scraping"). The product so obtained, called "scrape," or hard turpentine, or hard gum, is of a dingy white color, more or less mixed with woody particles and dust, and contains only half of the quantity of volatile oil obtained from the dip or soft turpentine.

In the first season the average yield of the dip amounts to 280 barrels and of the scrape to 70 barrels. The first yields 6½ gallons of spirits of turpentine to the barrel of 240 pounds net, and the latter 3 gallons to the barrel, resulting in the production of 2,000 to 2,100 gallons spirits of turpentine and 260 barrels of resin of higher and highest grades. The dippings of the first season are called "virgin dip" when almost without color, and white virgin dip, from which the finest and most highly priced quality of resin is obtained perfectly white, transparent, showing but the faintest tint of straw color, which enters the market under the grades of "water white" WW, and "window glass" WG. The next grades of resin obtained by the distillation of the turpentine dipped during the latter part of the same season, the "second virgin dip," are of a decided straw color and designated by the letters N. M. K. (See Distillation.)

In the second year from five to six dippings are made, the crop averaging 225 barrels of soft turpentine; the scrape is increased to 120 barrels, making altogether about 2,000 gallons of spirits. The rosin, of which about 200 barrels are produced, is of a lighter or deeper amber color, and perfectly transparent, of medium quality, including grades "I," "H," "G." In the third and fourth year the number of dippings is reduced to three. With the slow flow over a more extended surface, the turpentine thickens under prolonged exposure to the air and loses some of its volatile oil, partly by evaporation and partly by oxidation. To the same influence, no doubt, the deeper color of the crude turpentine is to be ascribed. In the third season the dip amounts to 120 barrels, the scrape to about 100 barrels, yielding about 1,100 gallons of spirits of turpentine and 100 barrels of rosin of a more or less dark-brown color, less transparent, and graded as "F," "E," "D."

In the fourth and last year three dippings of somewhat smaller quantity of dip than that obtained the season before and 100 barrels of scrape or hard turpentine are obtained, with a yield scarcely reaching 800 gallons of spirits and 100 barrels of rosin of lowest quality from a deep-brown to almost black color, opaque, and heavier in weight, classed as "C," "B," "A." After the fourth year the turpentine is generally abandoned.

Owing to the reduction in the quantity and quality of the raw product, resulting in a smaller yield of spirits and of lowest grades of rosin, it is not considered profitable by the larger operators to work the trees for a longer time. In North Carolina the smaller landowners work their trees for eight to ten successive seasons and more, protect the trees against fire, and, after giving them rest for a series of years, apply new boxes on spaces left between the old chips ("reboxing") with good results.

Distillation.—The process of distillation requires experience and care in order to prevent loss in spirits of turpentine, to obtain the largest quantities of rosin of higher grades, and to guard against overheating. After heating the still somewhat beyond the melting point of crude turpentine, a minute stream of tepid water from the top of the condensing tub is conducted into the still and allowed to run until the end of the process; this end is

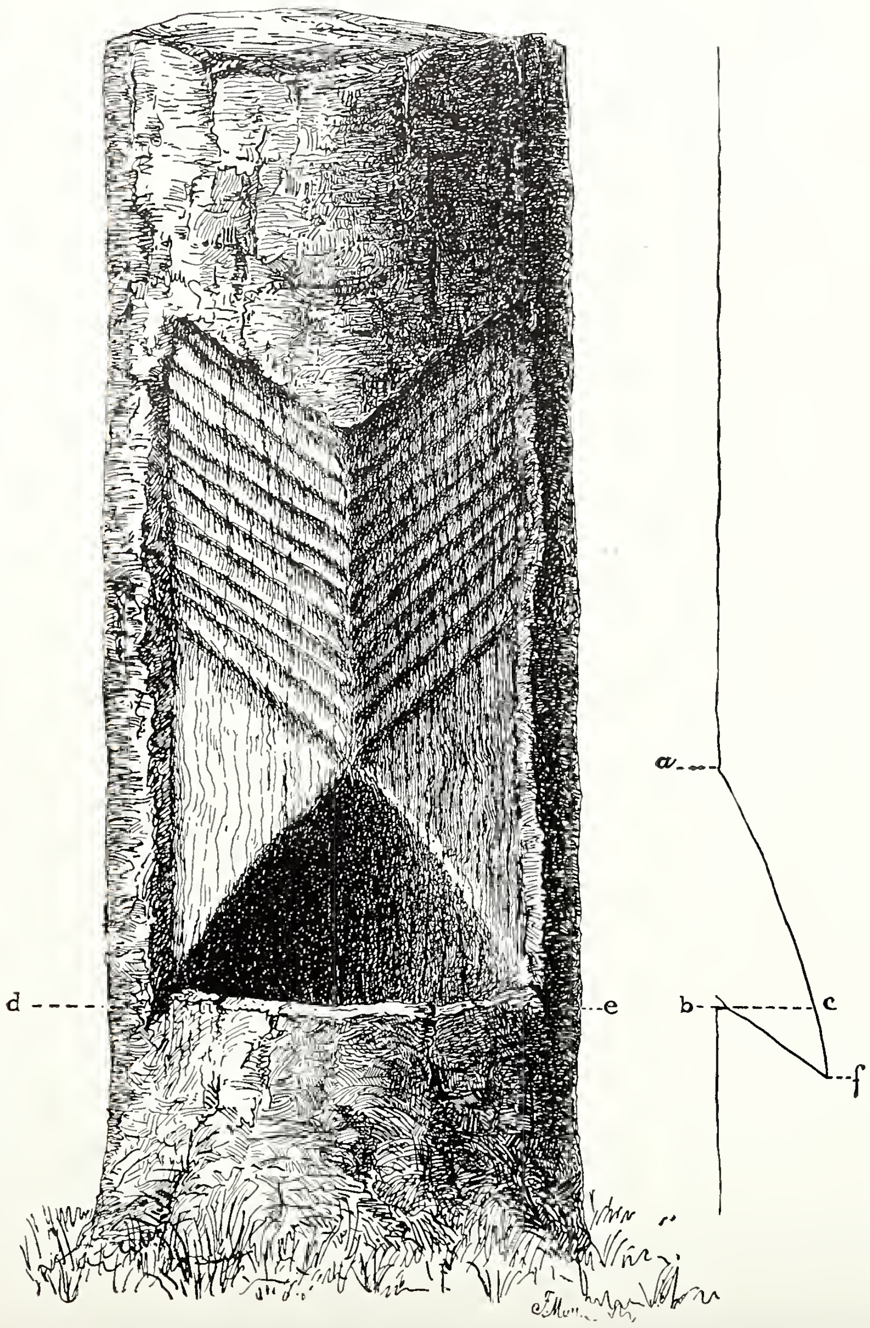


FIG. 1.—AMERICAN PRACTICE OF BOXING AND CHIPPING.

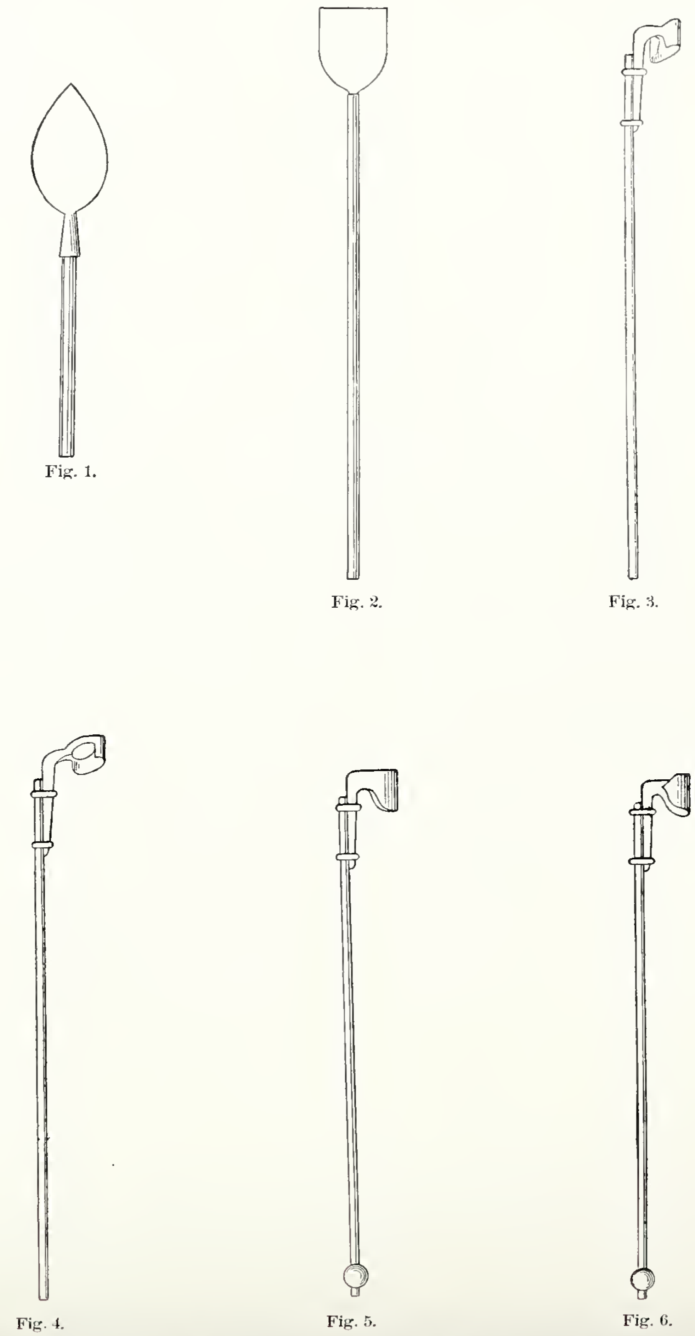


FIG. 2.—TOOLS USED IN AMERICAN PRACTICE OF TURPENTINE ORCHARDING.

indicated by a peculiar noise of the boiling contents of the still and the diminished quantity of volatile oil in the distillate. On reaching this point the heating of the still and the influx of water has to be carefully regulated. After all the spirits of turpentine has distilled over, the fire is removed, and the contents of the still are drawn off by a tap at the bottom. This residuum, the molten rosin, is first allowed to run through a wire cloth and is immediately strained again through coarse cotton cloth, or cotton batting made for the purpose, into a large trough, from which it is ladled into barrels. The legal standard weight of the commercial package is 280 pounds gross, no tare being allowed.

The finest grades of rosin are largely used in the manufacture of paper, for sizing, of soaps, and of fine varnishes; the medium qualities are mostly consumed in the manufacture of yellow soap, sealing wax, in pharmacy, and for other minor purposes, and the lower and lowest qualities are used for pitch in ship and boat building, brewer's pitch, and for the distillation of rosin oil, which largely enters into the manufacture of lubricating agents.

A turpentine distillery, on the basis of twenty crops, can be said to produce, during the four seasons the boxes are worked, about 2,400 casks, or 120,000 gallons, of spirits of turpentine and from 11,500 to 12,000 barrels of resin, or 2,800,000 pounds (the lowest grade BA excluded), at a value of about $60,000 at average prices. The prices of spirits of turpentine vary from 28 cents to 40 cents a gallon, even during the same season, according to supply and demand in the market. The quotations on December 31, 1892, at Wilmington, were 28 cents for spirits and $1.91 for resin in the average down to grade C. The prices for different grades were per barrel: WG, $3.65; N, $3.10; M, $2.85; K, $2.15; I, $1.45; H, $1.15; G, $0.92; F, $0.85; E. D. C, $0.82.

Cost of establishment of plant and of working the crop.—Lands with the privilege of boxing the timber for the term of four years are rented at the rate of $50 per crop of 10,000 boxes (about 200 acres with 4,000 to 5,000 trees). The establisment of plant for the working of twenty crops requires an investment of about $5,000, including the still, houses, sheds, tools, wagons, and working animals, mostly mules.

The following statement, made by an operator of many years' experience, exhibits the actual expenses incurred for the working of one crop during four years; the work is for the greatest part done by the job:

Chopping 10,000 boxes	$125.00
Inspecting and tallying the same	15.00
Cornering 10,000 boxes	12.00
Raking around the trees, at $10 per season	40.00
Chipping boxes during 111 weeks, at $5 per week	555.00
Dipping crude resin, 650 barrels, and scraping 460 stands, at 30 cents	333.00
Hauling dippings and scrapings, at 30 cents per barrel	333.00
Distilling at 20 cents per barrel	222.00
Spirit barrels, 122, at $2.80	305.00
Making and filling 795 barrels resin, at 30 cents	238.50
Superintendence of the crop	80.00
Total working expense of crop	2,258.50
Rent of land for one crop	50.00
Cost of one crop	2,308.50

Total expense of operating a plant of 20 crops during four years:

Labor,[1] rent and materials	$46,170.00
Interest on capital invested, $5,000, at 6 per cent	1,200.00
Loss by depreciation of plant, 10 per cent per year for four years	2,000.00
Taxes and incidentals	630.00
Total	50,000.00

Yield.—It appears that the yield of the crop of 200 acres distributes itself about as follows:

	Dip.	Scrape.	Total crude turpentine.	Total yield.	Scrape.	Spirits.		Rosin.
	Pounds.	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*	*Gallons.*	*Per cent.*	*Barrels.*
First year	67,200	16,800	84,000	30.9	20.0	2,100	34.4	260
Second year	54,000	28,000	82,800	30.5	34.8	2,000	32.8	200
Third year	28,800	24,000	52,800	19.5	45.5	1,100	18.0	100
Fourth year	28,000	24,000	52,000	19.1	46.1	900	14.8	100
	178,000	93,600	271,600	100.0	29.0	6,100	100.0	669

If we assume that 4,500 trees produce these amounts in four years, the yield per tree in crude turpentine is about 60 pounds. The result at the still would indicate that each tree furnishes between $1\frac{1}{4}$ and $1\frac{1}{2}$ gallons of spirits and one-eighth of a barrel, or 30 pounds, of rosin of better grade, or at best 75 cents' worth of product during the four years, which it has cost 55 cents to produce, leaving 5 cents net per tree per year, or from $1 to $1.25 per acre.

[1] Laborers are paid $1 to $1.25 per day; one man chips 10,000 to 12,500 boxes per week by the job. A saving is made now in most localities in the matter of barrels and freight by using kerosene tanks on cars, holding 3,500 gallons, into which the spirits are filled directly from the still.

From the fact that 4,000 acres of timber land (20 crops of 200 acres each) during four years' working produce 120,000 gallons of spirits of turpentine, or $7\frac{1}{2}$ gallons per acre and year, it follows that to produce the 17,000,000 gallons reported as the annual product, not less than 2,250,000 acres must be in orchard; and since the yield of the first year represents 35 per cent of the total annual yield, at least 800,000 acres of virgin forest are newly invaded annually to supply the turpentine stills in operation.

INSPECTION LAWS RELATING TO RESINOUS PRODUCTS.

In several of the Southern States laws have been passed regulating the inspection of turpentine, etc., and defining its grades. The principal of these are as follows:

Virginia.—Barrels to be full of good, clean, sound, and merchantable tar, pitch, or turpentine, and to hold $31\frac{1}{2}$ gallons.

North Carolina.—Soft turpentine barrels to weigh 280 pounds gross, and hard turpentine, 240 pounds; pitch, 32 gallons to the barrel. Turpentine, tar, or pitch to be free from fraudulent mixtures. Casks to be of good seasoned staves, three fourths of an inch thick, and not over 5 inches wide; not less than 30 nor over 32 inches long. Heads not less than 1 nor more than $1\frac{1}{2}$ inches thick. To have 12 hoops to a cask, except hard turpentine, which may have 10 hoops. Water is declared not a fraudulent mixture of tar. Tar and turpentine barrels not limited as to weight, but the weight to be marked and certified. Turpentine to be branded "S" or "H" for soft or hard, and to show the initials of the maker's name. The inspector of naval stores at Wilmington is to gauge all spirits of turpentine.

South Carolina.—A barrel of crude turpentine to weigh 280 pounds gross.

Georgia.—Inspectors of turpentine, etc., may be appointed by cities, and their duties prescribed. Soft turpentine to be put up in barrels, as in North Carolina, and to be branded "V" for virgin turpentine, "S" for yellow dip, and "H" for hard.

Florida.—The governor may appoint inspectors of tar and turpentine. Makers required to brand their initials on the barrels. Inspectors are to mark the products that come under their notice as follows: "V" for pure virgin dip, "D" for pure yellow dip, "S" for pure scrape. If the first two of these be impure or mixed, the "V" or "D" to be inclosed in a circle. If the scrape is not passable, it is marked with an "X" in a circle.

Allowances and deductions are to be made on turpentine with reference to the following particulars:

(1) When virgin dip is dipped from burnt boxes, or contains burnt cinders or sand.

(2) When virgin dip is mixed with chips, bark, or other impurities.

(3) When virgin dip is mixed with yellow dip, or scrape.

(4) When yellow dip is mixed, or contains chips, straw, bark, scrape, or sand, or other impurities.

(5) When scrape contains more chips than are absolutely necessary to get it off, or dirt, or other impurities.

(6) When yellow dip, virgin dip, scrape, or tar contains water, or there is an excess of wood in the barrels containing it, or it is injured by long standing or leakage.

(7) When tar or turpentine of any class is contained in insufficient or unmerchantable barrels.

The size of barrels is fixed at 30 to 32 inches in length, and the weight 280 pounds gross for turpentine and 320 for tar. Allowance is to be made for deficiences, and records are to be kept, but inspection is not obligatory upon the producers of tar and turpentine in this State.

Alabama.—Inspectors are to be appointed by the cities, and their duties prescribed by municipal law

TURPENTINE ORCHARDING IN EUROPE.

Austrian practice.—In Austria it is the black pine (*Pinus laricio*, var. *austriaca*) which is tapped for turpentine. The method is very similar to the American. In the spring, just before the sap rises (usually in March), a box (quandel) is cut into the tree about 1 foot above the ground (quandel). The box has about 3 inches depth and a breadth of from one-fourth to one-third of the circumference of the tree. From the corners of this box two upward diverging channels are notched, from the ends of which continues the scar or chip (sache). This is made with a carved hoe, $2\frac{1}{4}$ inches in width, by taking all the bark and the youngest two to four year old wood. The chip is at first made only about 2 inches high and increased very gradually, reaching during the first year 14 to 16 inches in height.

In the first year the chip is increased every week; in later years oftener, every four or five days. If the chipping is delayed longer the yield is smaller, since the resin thickens and incrustates the surface. The chipping is continued during eight to twelve seasons, and the chip increases every year at the rate of from 14 to 16 inches. The breadth remains even, and must never be more than two-thirds of the circumference of the tree. The time of chipping is from April to the beginning or the middle of October. In the first year most of the resin is liquid and flows into the box. Later, when it has to run a longer distance, so much of the volatile oils evaporates that the exudation thickens and must be scraped off the chip. So far this method does not differ from the American method, except as to the rapidity with which the chip is increased and the length of time the tree is worked. In order, however, to reduce the surface from which the

volatile oils may evaporate, a channel is formed near the place where the exudation occurs by making two converging cuts and inserting two pieces of wood, which conduct the resin into a narrower channel down to the box. Otherwise there seems to be no difference in the two methods.

Yield.—In experiments regarding the yield, the following results were obtained on sixteen trees, from 90 to 110 years old, under various conditions. During nine years of chipping there was obtained of resin (per tree and year) the amounts given in the statement following:

	Minimum.	Maximum.	Average.
	Pounds.	*Pounds.*	*Pounds.*
Small trees below 10 inches	2.9	6.18	4.64
Large trees over 10 inches	5.7	9.8	8.4

The last figure gives 75 pounds per tree altogether, or 25 per cent more than the average product in American practice. An 80-year-old growth, which was rented for twenty years, furnished in the tenth year of orcharding still a net rent of $12 to $18 per acre.

The scrape contains less spirits of turpentine, is mixed with chips of wood, and therefore obtains only two-thirds of the price paid for the dip. The amount of scrape depends, in the first place, on the surface of the chip; also on the temperature during the fall, warm weather producing more dips.

During the nine years of experimental chipping there were obtained for each 100 pounds of dip the following amounts of scrape:

	Minimum.	Maximum.	Average.
	Pounds.	*Pounds.*	*Pounds.*
Small trees below 10 inches	40.2	72.4	57.7
Large trees over 10 inches	38.9	62.9	47.3

From the gathering to the distillation of the resin a loss averaging about 3 per cent was experienced by the evaporation of the oil of turpentine. No other resin seems to be so rich in turpentine as that of the black pine, 100 pounds of resin yielding 14 to 20 pounds of spirits and 60 pounds of rosin.

During the same experiment, in the course of nine years, the following percentages of loss in the trees by death or windfalls occurred:

	Minimum.	Maximum.	Average.
Small trees below 10 inches	4	42.3	10.4
Large trees over 10 inches	1.3	27.3	8.3

Trees from 50 to 100 years old are tapped ten or twelve years before they are to be cut. The business is carried on upon a rent system per tree and year, under contract prescribing the dimensions and gradual extension of the chip and the time for chipping (usually till September 30) and scraping (not later than October 30), with heavy penalties in case of damage or excess of conditions. The total production in 1880—which has probably not materially changed since—was estimated at 13,288,000 pounds of resin, producing 9,260,000 pounds of rosin, 2,425,000 pounds of spirits, with an aggregate money value of about $300,000.

French practice.—Turpentine orcharding in France is carried on with more care than in any other country. The first difference between the methods in the United States and in France is that in the latter it is largely practiced in young plantations specially planted and protected for this particular business. The maritime pine (*Pinus pinaster* L. synon., *P. maritima*), which has been used in the celebrated plantations on the sand dunes along the coast and in the Landes of Gascony for over 2,000 square miles, furnishes the bulk of naval stores produced in France. The boxing or tapping is begun when the trees are 20 to 25 years old and is continued for a great many years. Trees have been known to have been boxed for more than two hundred years.

Two methods of boxing are practiced, which are known as *gemmage à mort* and *gemmage à vie*, or "bleeding to death" and "bleeding alive." The difference lies in the number of scars inflicted simultaneously. The bleeding to death is applied to trees which are to be cut out in the thinnings of a regular forest management and to those which are at the end of their usefulness. The illustration (Pl. XXX), here reproduced from Prof. L. Boppe's work on Forest Technology, represents a pine 200 years old, with more than fifty scars or chips, without apparently any ill effects on the life of the tree.

The "bleeding alive" is practiced on those trees which are to grow on, and hence must not be injured too much. They receive, therefore, one chip at a time. When this, after five seasons' workings, has attained a height of about 12 feet, the tree is allowed a rest of several years, and then another chip is opened, 6 or 8 inches from the old one, or else on the opposite side of the tree. In this way in time the whole circumference is chipped in alternating periods of bleeding and of rest until the trees are to be cut for lumber, when 100 to 125 years old or more. Sometimes exceptionally vigorous trees receive more than one chip at a time, but these are opened at different heights.

This successfully continued bleeding can, however, be carried on only by corresponding care in the manipulation. The important difference between French and American practice consists in this, that the former is more careful in the chipping and proceeds more slowly in enlarging the chip, which is made only 3 to 5 inches wide instead of 12 or 14. Further, in collecting the products with more care, the deep box cut into the tree in American practice is dispensed with and a lip and pot substituted.

The chipper begins his work in February or March by removing with a scraper from the whole portion of the tree that is to be chipped during the season, about 2 feet in height by 4 inches wide, the outer bark nearly to the wood. This is done to obviate the falling of bark chips into the pot, thus securing a cleaner product, and also to save the chipping tool. In the first week of March the chip is opened at the foot of the tree by making a triangular incision 3 to 4 inches wide and about $1\frac{1}{4}$ inches high, and not deeper than two-fifths of an inch. (Note the small size of the opening.) This chip is made with a specially and curiously fashioned hatchet, having a curved blade and a curved handle, difficult to make and use (Pl. XXX, fig. 1). The chip is enlarged (chipping piqnage) without increasing the width or even decreasing it. The art of the chipper consists in taking off just as thin a peel of wood as possible, and at each chipping he freshens up the old scar by removing another peel, taking care not to go deeper than two-fifths of an inch altogether. This chipping is repeated forty to forty-five times during the season, and during following seasons the chip is carried higher, until it reaches 12 to 13 feet in height, namely, 70 inches the first season, 30 inches each the following three seasons, and 38 inches the last season, when the tree is left to rest, and the wound heals up by the formation of new layers of bark and wood.

The cross-sections of trees bled through several periods twenty-four to twenty-seven years, and more (shown on Pl. XXXI) exhibit the manner in which the chips are distributed through the various seasons around the tree, and the manner in which the scars heal over. To be sure, the wood formed on the chips is irregular and therefore not serviceable for anything except fuel.

An experiment made in Austria on the black pine with the Hugues system (Pl. XXXI) produced more dip and less scrape and that purer, and with less work, owing to the greater capacity of the vessel and the smaller surface to be scraped being confined to the chip of the year. Besides, quantity and quality of the spirits and rosin were superior, namely, 78.5 pounds distilled gave—

	Common method.		Pot gathered.	
	Pounds.	*Per ct.*	*Pounds.*	*Per ct.*
Spirits turpentine	14.7 or	18.78	17.6 or	22.41
Rosin	47.3	60.22	52.9	67.37
Water	10.6	13.44	5.3	6.72
Scraps	1.5	1.96	....	......
Loss by evaporation	4.4	5.60	2.7	3.50
	78.5	100	78.5	100

Yield.—In a growth of 45 years of age, each tree produces from 6 to 10 pounds of resin each season more than we obtain from old trees. The yield per acre varies, of course, according to the

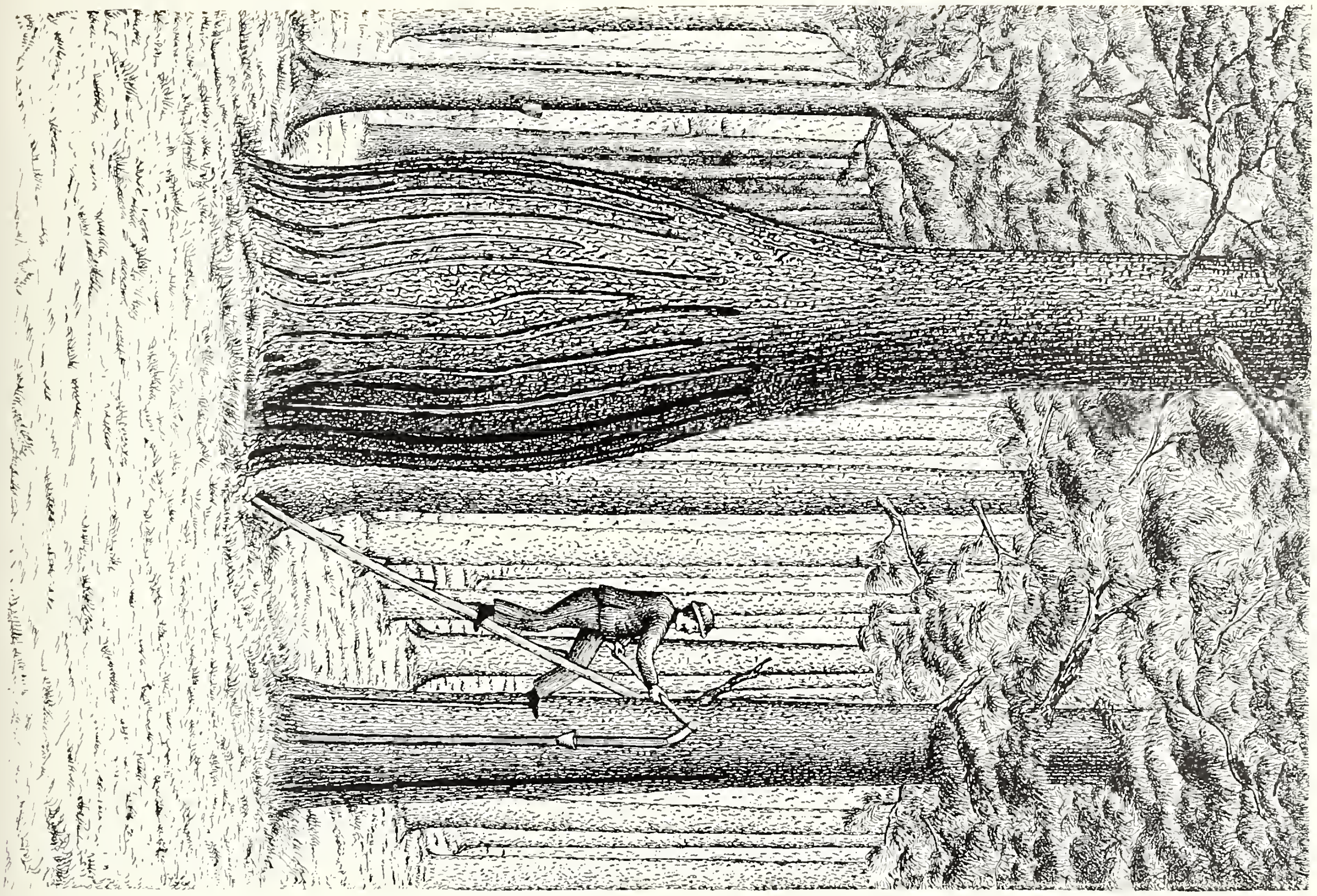


Fig. 1.—Turpentine Orcharding in France.

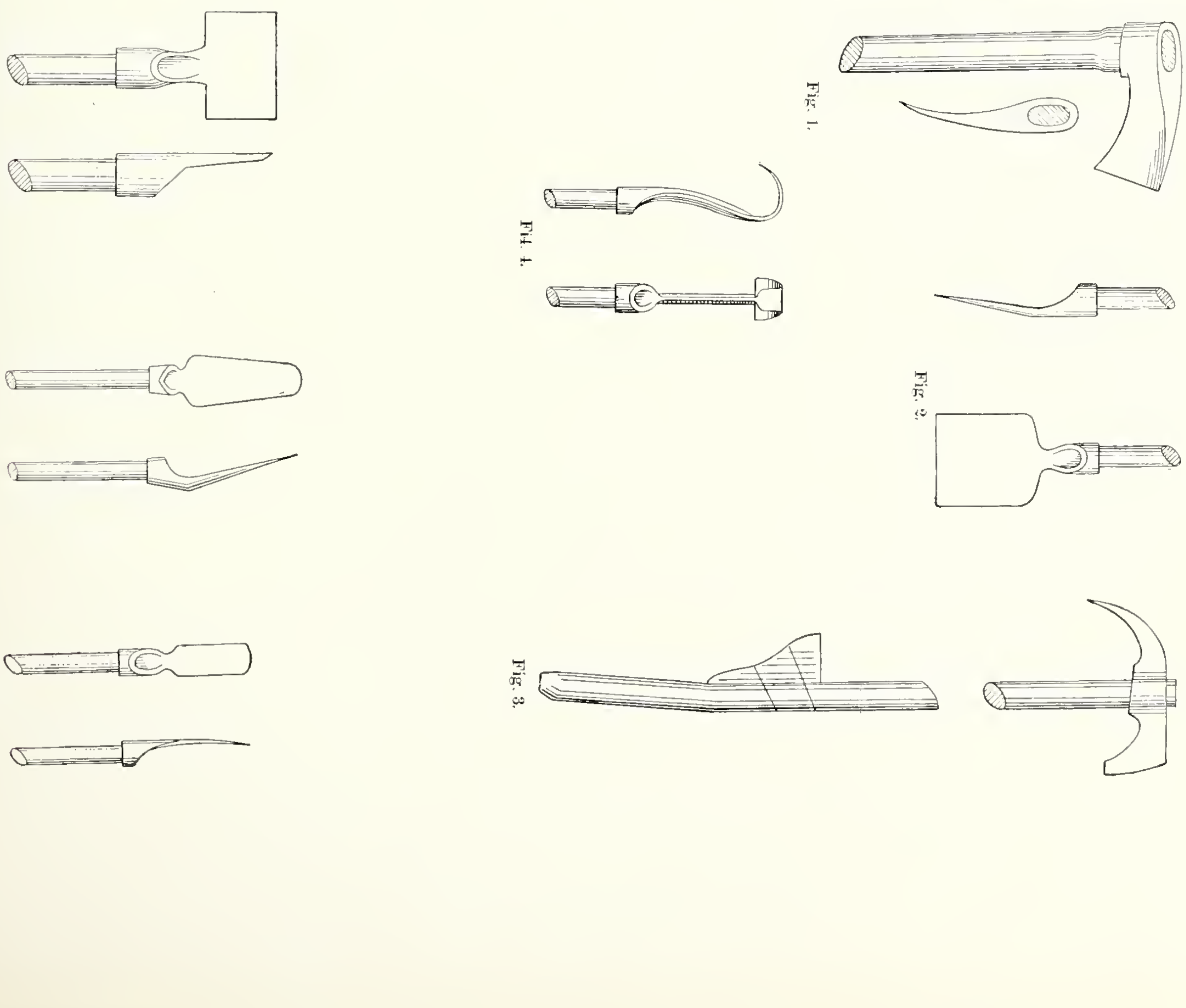


Fig. 2.—Tools used in French Practice of Turpentine Orcharding.

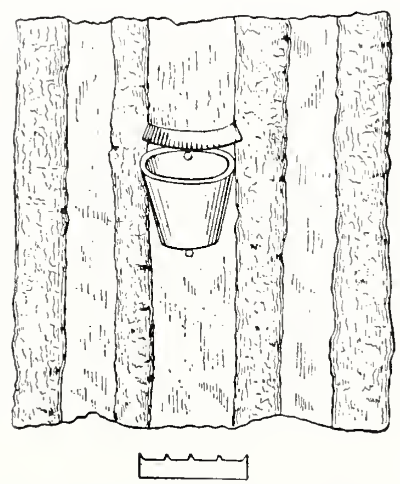


FIG. 1.—TURPENTINE GATHERING (HUGUES SYSTEM), TILL AND POT.

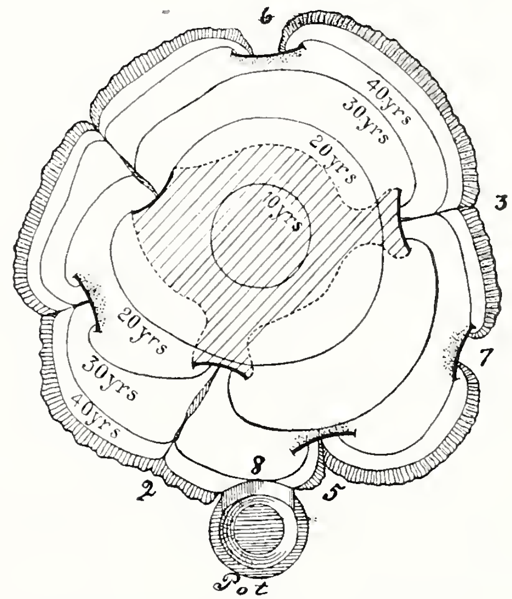


FIG. 3.—CROSS SECTION THROUGH BLED TREE.

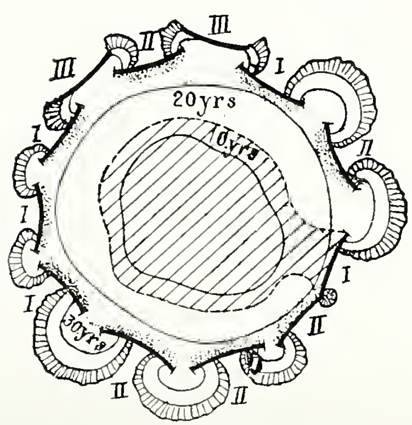


FIG. 2.—CROSS SECTION THROUGH BLED TREE.

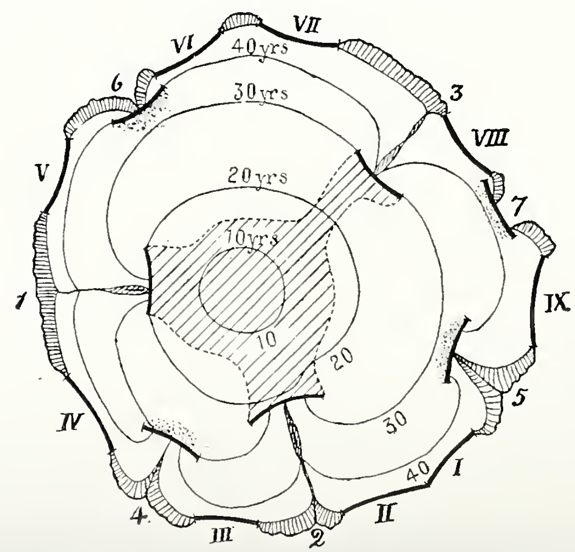


FIG. 4.—CROSS SECTION THROUGH BLED TREE.

age and the number of trees bled "to death" and bled "alive," as well as on the nature of the soil—the sand soil of the dunes produces more than the gravel and limestone soil. The weather and the care of the workman also influences the yield, so that the product per acre varies between 200 pounds of resin in younger (30 to 35 years old) growths to 400 pounds in older growths. The yield is said to be greatest in trees about 16 inches in diameter. If bled "to death," 200 to 250 pines, 8 inches in diameter, will yield about 500 pounds each year for three years. M. Bagneris mentions a pine about 50 inches in diameter which had 10 chips working simultaneously and yielded 12 to 14 pounds of resin annually. The men are paid by the cask of 517 pounds from $6 to $7, which allows them to earn about 80 cents to $1 per day. The price of the crude turpentine varies considerably from $8 per cask of 517 pounds. It reached the enormous figure of $58 during the American civil war. Orcharding in France is usually carried on on half shares between timber-land owner and orchardist.

EXPLANATION OF PLATES.

Plate XXX.—Tools used in French practice.

The tools employed in the French method of orcharding are: An ax (la cognee) for cutting trees and for removing the course for the chip and for opening the lower cuts. An ax with a concave blade and a curved handle (l'abchot); this is the principal tool of the orchardist, and it serves exclusively for the opening of the chips. The blade is razor-like in order to make a sharp and smooth cut through the resin ducts. The irregular form of its handle and of its sharp edge make it an instrument difficult to manufacture and particularly difficult to use, and it is only after a long apprenticeship that it can be used with exactness and dexterity. (Fig. 1.)

A scoop (la pelle) is made of iron, with an edge of steel. It is fixed at the end of a wooden handle about 3 feet in length. This serves to clean the bottom part of the chip and particularly to draw out the resin from the reservoirs. Fig. 2.)

The barker (la barrasquite) has a blade, steel-plated, narrow, and curved, and is furnished with a handle 5 feet long. This instrument is used for barking the trees at the highest point where it is impossible to use the ax, and for gathering the resin from such places. (Fig. 4.)

Another kind of barker (le rasclet), much edged, having a handle 6 feet long, which is furnished with a step, is used in certain regions to continue the chip above the height of a man. Often the orchardist holds on by the handle of the "rasclet" and works with the hatchet. (Fig. 3.)

A third form of scraper (la pousse), having a handle 8 feet long, used for the same purpose, has the blade so bent as to permit the worker to stand at a distance from the tree, thereby avoiding, while working, the falling bark and dripping resin. (Fig. 5.)

A shorter scraper (le palot), with a handle only 3 feet long, replaces the scoop everywhere where the Hugues system does away with the dirt. It is used for cleaning, and is also used like a dibble at planting time for planting the acorns. (Fig. 6.)

A ladder made by cutting steps into a pine sapling, each step being held by a nail to prevent breaking, is used to reach the higher points.

The products are gathered from the chips or pots to a reservoir established in the forest, in a sort of basket with a capacity of about 20 quarts. It is formed by a cylinder of rough cork surrounded with wood, the bottom being a round slab, made fast with pegs. The handle is of willow.

A spatula (l'espatula) is used to remove the resin that adheres to the sides of the pots or transporting vessels. (Fig. 7.)

Plate XXXI.—Turpentine gathering—Hugues system.

In this plate fig. 1 exhibits the method of gathering turpentine by the Hugues system, and the use of the till and pot. While formerly the resin was allowed to run into a hole in the sand at the foot of the tree, since 1860, when the production was stimulated by the closing of the American sources of supply, an improvement on the crude method of collecting came into use. It consists in fixing a bent zinc collar or gutter cut from sheet zinc 8 inches long and 2 inches wide, with teeth (see figure) across the chip, which acts as a lip, and conducts the liquid resin into a glazed earthen pot or a zinc vessel of conical shape suspended below the lip. The pots are 6 inches high, 4½ inches at the opening, and 3 inches at the bottom, and hold about 1 quart. At first placed on the ground they are fastened each season above the old chip by means of a nail through a hole or otherwise (see figure). In this way, by shortening the distance over which the resin has to flow, the evaporation of the oil is reduced, and there is less liability of impurities to fall into the receiver. A cover over the pot is also sometimes used. The pots are emptied every fifteen or twenty days with the aid of a spatula (see Pl. XXX, fig. 7). The scrape is collected only twice in the season, in June and November.

Another improvement which reduces the amount of evaporation and assures cleaner resin consists in covering the chip with a board. This improvement (Hugues system) is said to yield more and purer resin; the yield is claimed to be about one-third larger, and the difference in price, on account of purity, 80 to 90 cents a barrel, while the cost per tree per year is figured at about 1 cent; besides, the proportion of scrape is considerably reduced. This (called galipot) is collected by hand, except the hardest impure parts (called barras), of which there is hardly any

in this system of collection. Not more than 17.9 per cent of scrape is expected, as against 29 in the American practice.

Figures 2, 3, 4 show cross sections of trees bled through several periods of years; also the manner in which chips are distributed, and healed scars.

MANAGEMENT OF TURPENTINE PINERIES.

When the yield of turpentine falls below a certain minimum, the time has arrived when the growth must be regenerated. All trees are then bled "to death" and cut as they give out, and the openings are seeded with pine seed and the reproduction is completed in four or five years. The young forest grows up uniformly, densely, and quickly, and when 10 or 12 years old it becomes necessary to thin out and to repeat the operation every five or six years, so that at the age of 20 the pines are nearly isolated. Then there are about 250 to 280 trees per acre, and bleeding "to death" is commenced at the rate of, say, 80 or 85 trees, which are to be taken out during the next four or five years. At the age of 25 another 80 are subjected to the operation, and at the age of 30 there may be left 100 to 125 trees per acre. At this age, when the trees are about 1 foot in diameter, bleeding "alive" is commenced on all trees. At the age of 60 to 80 years this number has dwindled down by casualties to 80 or even 65. If well managed these trees may last 120 to 130 years; otherwise, if bled too much, they will succumb in half the time. A rest of a year or more every fifth year is necessary to recuperate the trees. When the circumference of the tree has been all chipped, the old chips may be opened again.

In order to produce resin abundantly the trees must stand isolated, their crowns well exposed to the sunlight; but it is only necessary that the crowns should just touch, when the trees are sufficiently isolated.

The best producers are the short, stout trees, with well-developed crown and well set with branches. To endure tapping without injury, they should be at least 14 inches in diameter, with a bole of 20 to 26 feet to the first limb on the dunes and 40 to 50 feet in the landes. There is no definite relation between volume and resin production. In fact, there is but little known as to the conditions and physiological processes which give rise to the formation of resin, except that full, active foliage and heat seem to be essential factors.

GATHERING OF SPRUCE TURPENTINE.

The wood of the spruce contains few and rather narrow longitudinal resin ducts, but wider lateral ducts, which are strongly developed in the liber or new wood fibers. It is these that furnish the flow. Hence the methods of extraction used on the pines must be modified. In growths 80 to 100 years old the yield is about 127 pounds of scrape and 40 pounds of dip per acre. Here the scrape is the purer material, and, therefore, more expensive, the dip being more or less impure. The operation is harmful to the trees, as it is apt to induce red rot. The pitch known as Burgundy pitch is derived from the resin of this species.

The resin of the spruce has also the property of hardening very quickly on exposure to the air; therefore it does not flow readily enough from the chip to permit the methods used in the pines. In May or June two chips are made at the same time, 3 to 3½ feet in height and only half an inch in breadth, on opposite sides of the tree. They are cut with a specially curved sharp knife, and deep into the sapwood. In order to prevent stagnant water from collecting at the bottom, this is made pointed. The sides of the chip soon form callous, which would prevent the flow, and therefore the sides must be renewed every two or three years, or yearly, gradually widening the chip, so that after a series of years only two small strips of bark remain between the two chips. The renewing of the sides is done in summer, so that they may protect themselves before winter sets in by forming new callous. In some localities alternate chips are made every two years, instead of enlarging the original one. The bleeding is continued for ten to fifteen years, and the yield per tree and year averages 1 pound scrape and 1⅓ pounds of dip.

GATHERING OF LARCH TURPENTINE.

The larch contains resin ducts of very large diameter, and the resinous contents are found mainly in the heartwood. The trees very often contain frost splits in the heart, in which the resin collects. The trees are bored into about a foot above the ground in horizontal direction. The

bore-hole, being 1 inch in diameter and reaching into the center, is closed with a wooden stopper. This hole fills up during the summer and the resin is taken out with a half-cylindrical iron and then closed up. One tree will furnish per year one-fourth to three-eighths of a pound (120 to 180 grams) of resin. If the bore-holes were left open from spring to fall, the yield could be increased to 1 pound, but the resin would be impure, would contain less spirits of turpentine, and the tree would be damaged. One bore-hole suffices for the whole period of orcharding, which is usually carried on for thirty years. With small amount of work and with a price two to three times that of the black pine turpentine, and no injury to the trees, this industry is quite profitable in spite of the small yield.

GATHERING FIR TURPENTINE.

The resin of the firs occurring mainly in isolated resin vesicles or cells and most abundantly near the bark (blisters), this is gathered by means of an iron pot with sharp-pointed till, with which the vesicles are pierced. From the European fir in this way the Strasburg turpentine used to be gathered; now the practice is nearly abandoned. The Canada balsam is gathered similarly from our own fir, *Abies balsamea.*

EFFECTS OF TURPENTINE ORCHARDING ON TIMBER, TREE, AND FOREST, AND SUGGESTIONS FOR IMPROVEMENT ON AMERICAN PRACTICE.

The turpentine industry can be carried on, but usually is not, without detriment to the value of the timber, to the life of the tree, and to the condition of the forest. The present practice, however, in the United States is not only wasteful but highly prejudicial to present and future forestry interests.

Effect on the timber.—As far as the timber of bled trees is concerned, it has been shown by the work of the Division of Forestry that the heartwood, the only part of the tree which is used for lumber, is in no way affected directly by the process of tapping. Not only has its strength been shown to be in no wise diminished, but since the resin of the heartwood does not participate in the flow, being nonfluid, the durability of the timber, as far as it depends on the resinous contents, can not be impaired by bleeding. Indirectly, however, by the boxes and large-sized chips, a considerable loss of timber in the best part of the tree, the butt log, occurs, which is avoidable. The parts surrounding the scar are furthermore rendered somewhat harder to work by an excess of resin which accumulates on and near the wound, tending to "gum up" tools. Indirectly, also, a considerable proportion of boxed timber becomes defective if not used at once or, if left on the stocks exposed for a series of years to destructive agencies, such as fires, followed by fungus growth and attack of beetles. The larvæ of large capricorn beetles bore their way through the soft wood formed in the shape of callous surrounding the borders of the chip and through and beyond the sapwood. Through the innumerable fissures which are caused by repeated fires, air and water charged with spores of fungi find entrance into the body of the tree, causing decay, the damage increasing every year, so that from this cause alone the timber from a turpentine orchard abandoned for ten or fifteen years was at the sawmill found damaged to the extent of fully 20 per cent.

Another prospective loss in timber is occasioned by the tapping of undersized trees which are not ready for the saw. Even if the tree survived all the changes of the years following the bleeding and healed over the wound, the timber formed after the process, at least in the portion of the tree which carried the chip, is inferior and not fit for sawmill purposes on account of malformations and change of grain. The loss of timber by fire is also only an incidental effect of careless management.

Effect on trees.—No doubt the normal life of the tree is interfered with by bleeding; not that the resin is of any physiological significance to the life of the tree, but the wound inflicted in the tapping, like any other wound, interferes with and reduces the area of water-conducting tissue. This interference may be so slight as practically to have no effect, or so great as to kill the tree sooner or later if other conditions are unfavorable. The experience in France shows that with care (narrow chips and periods of rest, which permit callousing of the scar) trees may be bled for long periods and attain old age (see p. 158); it also shows how fast a tree may be bled to death, if this is desired. (See Pl. XXX.)

While the exudation of the resin covering the excoriated surface and the accumulation of resin in the wood near the surface act as an efficient antiseptic and firm protection against atmospheric influences, access of fungi and of insects to the interior of the tree—superior to any callous—it also endangers the life of the tree if exposed to fire, since the resin is highly inflammable, and the heat produced by its flame is capable of killing the trees outright. It is, therefore, again, this indirect effect which exposes the trees of the turpentine orchard to extra risk, even though the operation was carried on with due care and consideration for the vitality of the tree.

Effect upon the forest.—What has been said regarding the effects upon timber and trees applies naturally to the forest as a whole. With proper methods and proper care the turpentine industry need not be detrimental to the full and profitable utilization or the successful regeneration of the forest. In France the turpentine orchard is generally as well managed—with exceptions, of course—as any other forest property. Unfortunately, the ignorance and carelessness of our turpentine gatherers, as well as of the entire community regarding forestry matters, lead to most disastrous results.

The coarse, irrational manner of cutting boxes into the tree for gathering the dip, while reducing the yield of the valuable oil, weakens the foot of the tree, and those receiving more than one box or being of small size are generally sooner or later blown down; the broad chips, out of proportion to the size and vitality of the tree, cause many to die before they have yielded what they could; the same charge of wastefulness may be made against the methods of chipping and of collecting the resin, both of which reduce the yield considerably. But the greatest loss is that occasioned by the fires, carelessly handled by the orchardist himself in trying to protect himself against it, and still more carelessly allowed by the community to rage over large areas one season after another. In the orchard their destructiveness is increased by the broad resinous surfaces at the butt of the trees by the blown-down trees and the débris of the dead trees standing or lying on the ground. Dr. Mohr observes—

> The trees which have not been killed outright by the fire, or have altogether escaped this danger, are doomed to speedy destruction by bark beetles and pineborers, which find a breeding place in the living trees blown down during the summer months, the broods of which rapidly infest the standing trees, which invariably succumb to the pest in the same season. Hence, the forests invaded by the turpentine men present, in five or six years after they are abandoned, a picture of ruin and desolation painful to behold; and in view of the destruction of the seedlings and younger growth, and of the vegetable mold, season after season, all hope for the restoration of forest life is excluded.

SUGGESTIONS FOR IMPROVEMENT.

No radical improvement on existing practice can, of course, be expected until the turpentine orchardists themselves can see that present conditions and methods are detrimental to their business, and can persuade the community that it is to the mutual interest of both community and orchardist to allay the fire nuisance.

Forestry—that is, rational use and management for perpetuity of our forest resources—will never succeed in our country until our communities discountenance the habits of the savages in the use of fire and learn that civilization consists in making nature do more than she voluntarily gives; in fact, that it consists in management, not in destruction, of natural resources.

It is the duty as well as the self-interest of the community to do all in its power to make rational management for continuity practicable, and the first step is to insure protection of individual property against loss, be it by depredation or by other preventable causes. Hence, protection against fire is a conditio sine qua non, if we would have rational and systematic management of our forest resources; for so long as forest property is made extra hazardous by lack of proper protection against fire the inducement to rob it of its best parts in the shortest time and then abandon it to its fate is too great.

I would refer here to another part of this report, in which the general legislation for fire protection has been outlined (pp. 183–188). In the States or portions of States in which turpentine orcharding is practiced additional provisions would be necessary.

Regarding the practice in the technical operation of tapping, legislative regulations are probably out of the question, the spirit of our institutions being against interference in the use of private property except where such use is directly injurious to other persons. Otherwise it would be desirable, for the indirect benefit of the community, and especially its future, to prescribe lowest size of trees to be tapped and broadest chip permissible.

The orchardist's own interest, if he owns the forest and proposes to make the most of it, or the owner's interest, if he leases it for turpentine orchard, would dictate the following considerations, which I have formulated into a set of instructions:

(1) Attend to the firing of the brush, when preparing for orcharding, at a season and time when a smoldering fire can be kept up which will not kill young growth and will not consume to ashes the vegetable mold.

(2) Abandon the "boxing" system and substitute the movable pot with cover and lip.[1] (See Pl. XXX, fig. 1.) By this the tree is less injured or liable to injury, and a larger amount of valuable dip and a smaller proportion of scrape is insured. The cost of making and cornering boxes—a wasteful operation—averages about 1½ cents per box, while the cost of pots is very much higher (heavy tin or zinc iron pots might be used more cheaply); but if the orchard is worked for longer time, as proposed in the following, the cost per year will be reduced and amply repaid by better yield.

(3) Tap only trees large enough to make a good saw log, not less than 12 inches at the butt. Not only will such trees yield in better proportion to the labor expended, but the younger trees when left, after the saw timber fit for the saw has been taken, will assist in the reforestation by shedding their seed, and will in a few years have grown to proper size both for profitable tapping and profitable lumbering.

(4) Reduce the chip in breadth to not over 3 inches, and rather work more chips at a time on the same tree, if good sized; not more, however, than one for each foot in circumference simultaneously, so that a tree 1 foot in diameter would carry, say, three of these narrow chips, evenly distributed. Thus the tree will be kept in full activity and yield more turpentine for a longer time.

(5) Before starting the chip remove the rough bark down to a thin (reddish) skin for the breadth of 4 inches and, say, 2 feet in height, or a little wider than the chip is to be, and as high as it is to be worked for the season; this is for the purpose of keeping your pots clean of bark particles. Start the chip with as small an opening and as low down at the foot of the tree as is practicable for attaching the pot, and cut it triangular at the base, so as to allow any water to readily flow off, preventing its collection and consequent fungus growth.

(6) Do the chipping as gradually as possible, remembering that the flow depends mainly upon the number of longitudinal ducts cut through transversely and kept open. A rapid increase in height of the chip is a useless waste; the chipping is done simply to remove the clogged-up ends of the ducts; the removal of one-fourth to one-third or at most one-half inch of new wood every five to eight days, according to the weather, will accomplish this end. As to depth, it is useless to cut deeper than the sapwood, since the heart does not yield any resin. Whether the French method of deepening the chip gradually and only to a depth of one-half inch at most or a cut through the entire sapwood at once is, on the the whole, more profitable, comparing labor and yield, remains to be ascertained by trial. Where trees are not to be managed for continuous bleeding, but are to be exhausted prior to their cutting for saw logs, it would appear proper to cut at once through the entire sapwood, using perhaps a sharp chisel for the work of chipping. When we have arrived at a time when the orcharding is done in young plantations managed for the purpose the more careful chipping of the French may be indicated.

(7) Do not collect the scrape more than once a year, in August or September, or early enough to give the trees a chance to protect their scars before winter sets in; but reduce the amount of scrape by using pots and lips and keeping these as close as practicable to the top of the chip. In this way the superior yield will pay for the greater care.

(8) Remember that it is more profitable to prepare for operating a given area for ten to fifteen years instead of three to four years, since many necessary expenditures remain the same whether the operation is carried on for the shorter or longer period, and hence in the latter case are distributed through a longer term. With the above methods and proper care an orchard may be

[1] Since the above was written (in 1892) the pot or cup system has been experimentally tried by J. C. Schuler of West Lake, La., the patentee of a special pot, described in Bulletin 13, Division of Forestry. The patentee admits the extra cost for a crop of 10,000 cups for two seasons as $460 against $190 under the old system, but the increased yield of crude turpentine for the two years is claimed as 195 barrels at $3.50 per barrel or $410 in favor of the cup system.

worked profitably four or five times as long as under present methods, and hence many precautions, especially against fire, such as ditches, roads, etc., to arrest the fire, too expensive if the orchard is soon to be abandoned, may be employed with advantage.

(9) If present methods must prevail and protection against fires can not be had, because the community is still too uncivilized or blind to its interests, do not subject your valuable timber to turpentine orcharding unless you can dispose of it to a sawmill immediately after the orchard is abandoned. Otherwise the loss of timber by fire is apt to wipe out all profits made by the orchard.

IMPROVEMENTS IN THE DISTILLATION OF THE CRUDE TURPENTINE BY THE APPLICATION OF STEAM.

In the ordinary way, the distillation of the crude turpentine, yielding the largest quantity of spirits of turpentine and finest quality of rosin, can not be carried to the total extraction of the volatile oil without impairing the quality of the residuary product. The higher grades of rosin are still retaining a considerable amount of spirits. To prevent such loss distillation by steam has been resorted to. This innovation seems, however, not to have received the deserved attention. From the latest information it appears that this method has proved completely successful at a turpentine distillery in New Orleans; there, by its introduction, an increase of fully 30 per cent is claimed over the yield of spirits of turpentine obtained by distillation with the open fire, the grade of rosin remaining unaffected.

PRODUCTS OF THE DESTRUCTIVE DISTILLATION OF THE WOOD OF THE LONGLEAF PINE.

The air-dried wood of the longleaf pine in its normal condition has been found to contain from 2 to 2¾ per cent of volatile oil, taking the specific gravity of spirits of turpentine at 0.87 and the weight of 1 cubic foot of the air-dried wood at 43 pounds. The spirits is obtained by subjecting the wood to the action of superheated steam in the same retorts in which its destructive distillation is carried on, a process with which its production direct from the wood is invariably connected, and of which it forms the first step. The quantity of spirits of turpentine obtained varies largely. As stated by one operator, it differs all the way from 5 to 18 per cent, according to the wood being fresh cut or dry, and to the different parts of the tree from which it is taken. From the results of numerous experiments made on a large scale in different parts of the longleaf-pine region, it can be assumed that 1 cord of wood, green and of different degrees of dryness, yields, on the average, about 15 gallons of an impure spirits of turpentine. Owing to the presence of empyreumatic substances of yellow color it becomes darker on exposure to air and of an empyreumatic odor. It is easily freed from its impurities by redistillation; thus rectified, the product is perfectly clear, colorless, and almost odorless, save a faint woody smell, answering all the purposes for which the spirits of turpentine obtained from the rosin is used. In 1881 Mr. William Mepan, of Georgia, secured a patent for the utilization of the wood wasted at the sawmills, of the refuse left on the ground in the logging camp and in the turpentine orchard, for the production of spirits of turpentine, pyroligneous acid, tar, and charcoal. By the operation of the apparatus of the patentee, on exhibition at the Atlanta International Exposition (in 1882), 600 pounds of dry, highly resinous wood, so-called lightwood, yielded—

	Pounds.
Spirits of turpentine	21¼
Pyroligneous acid	95
Heavy oils and tar	150
Charcoal	127
Water and gas	206¾
Total	600

Amounting to a yield by the cord of 24 gallons of spirits of turpentine, 88 gallons of pyroligneous acid, 120 gallons tarry and heavier oily products, and 56 bushels of charcoal.[1]

In several experiments made at the same place slabs taken from the sawmill yielded (to the cord) from 12 to 14 gallons of spirits of turpentine, 200 to 250 gallons of weak pyroligneous acid, from 64 to 108 gallons of tar and heavier oils, and from 50 to 60 bushels of charcoal. The operations subsequently carried on by the same parties in retorts of a capacity of about 6 cords of

[1] Report of awards at the Atlanta International Exposition in 1882.

wood showed similar results. In the attempt made at Mobile by Mr. Maas, about fifteen years past, in connection with a sawmill—soon abandoned, however—the results were about the same. From a cord of green slabs 12 gallons of turpentine were distilled and 150 gallons of tarry and oily substances. The rectified spirits of turpentine was found not to differ sensibly from the product of the rosin. At the works of the Yellow Pine Wood Distilling Company at New Orleans, worked under the patent and superintendence of Mr. E. Koch, every kind of mill refuse, pine knots, stumps, branches, etc., are used. The patentee has kindly furnished the following information about the apparatus employed and the way it is being worked: The material is cut in short pieces, loaded in iron cars, which are run into steel retorts, 20 feet long and 8 feet in diameter, provided with rails, and holding 3 cords of wood; doors are closed tight, superheated steam is let in, and at the same time a moderate fire is started in the furnace. The distillation proper of the spirits begins in about six hours at a temperature of 300°, increasing during the next four hours to 350°, until the distillate ceases to run; at this stage the steam is shut off and the destructive distillation by the open fire is proceeded with; under the gradual increase of the temperature from 350 to 900 degrees the distillation is continued through the following fifteen hours, the whole operation consuming about twenty four hours. The residue in the retort is a charcoal of good quality. The quantity of spirits of turpentine obtained from 1 cord varies from 5 to 18 gallons, of heavier oils and tarry products known as dead oil or creosote from 60 to 100 gallons, and of stronger acid (of a specific gravity 1.02) 60 gallons, or of weaker acids 120 gallons. The gas produced is used for fuel. The capacity of this plant is 6 cords of wood in twenty-four hours. By the increase in the value of dead oil that has taken place during the past five or six years the destructive distillation of the wood of the longleaf pine is placed financially on a more promising basis than ever before. If the enormous amount of raw material be considered, which has heretofore gone to waste at the sawmills and in the forest, but by this process may be turned to a profitable use, this industry is capable of the widest extension, and can not fail to add other resources of income to those already derived from the forests of longleaf pine.

With the augmenting demand for the mixture of heavier hydrocarbons and chryselic (phenylic) compounds known in the trade as dead oil, creosote, or pine oil for the impregnation of timber for the purpose of preventing its decay and destruction by the teredo, the distillation of the wood of the longleaf pine is at present carried on with the main object of securing the largest yield of dead oil. According to the statements of Mr. Franklin Clark (see Columbia College Quarterly), made in his paper on the subject, for this purpose the most resinous wood is preferred with which the retorts are charged.

These retorts, cylindrical in shape, made of wrought-iron or steel plates, and about three times as long as they are wide, are of a capacity to receive little over a cord of the perfectly air-dried wood. The distillation is effected by the open fire and the condensation of the distillate by the ordinary worm condenser. The light oils running over first at a temperature of from 350 to 500 degrees, of a specific gravity of 0.88 to 0.90, are of a dark-red color; as soon as their density has increased to the latter figure they are caught separately. After twelve or fifteen hours, when the temperature has reached 600 degrees and the density of the oil is 0.98, with the formation of the chryselic compounds the aqueous distillate at this stage shows a higher percentage of acetic acid, increasing with the rise of the specific gravity of the oil. The operation is generally finished at a temperature not exceeding 900 degrees. The process is terminated at the end of twenty-four hours.

The charge of the retort, averaging 4,575 pounds of resinous, air-dried wood (little more than a cord), yields—

Light oil (of sp. gr. 0.875 to 0.95) .... gallons..	13
Heavy pine oil or dead oil (sp. gr. 0.95 to 1.04) .... do....	73½
Pyroligneous acid (sp. gr. 1.02) .... do....	185
Or a mean yield of—	
Pyroligneous acid (sp. gr. 1.02)	1,527 pounds, or 34.37 per cent.
Total of oily products	729 pounds, or 15.94 per cent.
Charcoal	1,511 pounds, or 33.04 per cent.
Gas	761 pounds, or 16.64 per cent.

On settling, the pine oil—that is, the whole of the oily products of the wood—separates from the acid as a black or red oil, with a specific gravity from 0.97 to 1.30. For the purpose of

creosoting it is subjected to a process of partial distillation, by which the separation of the lighter oil is effected, and the percentage of the phenylic compounds and of the heavy hydrocarbons to which the creosoting process owes its merits is increased.

The pyroligneous acid is of a yellowish or reddish color and contains 4 per cent of hydrated acetic acid. In its crude state it serves for the manufacture of pyrolignеate of iron, the so-called black dye, and for the preparation of acetate of lime, acetate of lead, and pure acetic acid. The light oil is used for dark paints, fit to cover metals and stone. It does not work well, however, on wood.

Development of a Forest Policy.

HISTORICAL.

The recognition that attention to satisfactory forest conditions is as necessary as to other economic conditions, has existed among a few wise heads since the beginning of the settlement of the country. Thus William Penn, the founder and first legislator of Pennsylvania, as early as 1682, in his ordinances regarding the disposal of lands, stipulated that to every 5 acres cleared of forest growth 1 acre of trees should be reserved for forest growths by those who took title from him, a provision which was probably soon forgotten.

In 1640, only two years after its settlement, the inhabitants of Exeter, N. H., adopted a general order for the regulation of the cutting of oak timber, a precaution which other towns followed. In 1708 the provincial assembly of New Hampshire forbade the cutting of mast trees on ungranted lands, under a penalty of £100, and at that early time the province had a surveyor-general of forests, appointed by royal authority, for the purpose of preventing depredations upon timber.

A noteworthy effort to inculcate rational treatment of our forest resources, which took at least its incentive in these earlier times, although it came to a result much later, is that made by two noble Frenchmen, botanists, André Michaux and his son André François, who between the years 1785 and 1805 explored and studied the forest flora of the United States, and, besides shorter discussions on the subject, published a magnificent work on the same, the North American Sylva, in three volumes.

The latter, André François Michaux, translated his love and zeal for this study into practical action by leaving two legacies for the study of silviculture in the United States.

In his will, dated September 4, 1855, A. F. Michaux made the following provision:

> Wishing to recognize the services and good reception which my father and myself, together and separately, have received during our long and often perilous travels in all the extent of the United States, as a mark of my lively gratitude, and also to contribute in that country to the extension and progress of agriculture, and more especially of silviculture in the United States, I give and bequeath to the American Philosophical Society of Philadelphia, of which I have the honor to be a member, the sum of $12,000; I give and bequeath to the Society of Agriculture and Arts in the State of Massachusetts, of which I have the honor to be a member, the sum of $8,000; these two sums making 180,000 francs, or, again, $20,000. I give and bequeath the sole ownership to these two abovesaid societies, and the usufruct to my wife for her life.

This bequest did not become available until 1870. The American Philosophical Society at Philadelphia, being the trustee of one of the Michaux legacies, has devoted part of its income from this fund to aid in the beautification of Fairmount Park, especially by the propagation of various species of oaks; another part is devoted to popular lectures on subjects relating to forest botany and forestry.

The bequest to the Massachusetts Society for the Promotion of Agriculture is applied to aid the botanical garden at Harvard and the Arnold Arboretum, and to the occasional publication of pamphlets on forestry subjects. This society, founded in 1792, has also occasionally tried to encourage forest culture by paying premiums for successful forest plantations (especially in 1876). As early as 1804 such prizes were offered.

A similar society—the Society for Promotion of Agriculture, Arts, and Manufactures—in New York, founded in 1791, also considered it among its functions to foster forest culture by publishing in 1795 a report on the best mode of preserving and increasing growth of timber, an outcome of an inquiry by circular letter issued in 1791.

The Federal Government recognized the need of action as early as 1799—to be sure, only with reference to a certain kind of supplies, namely, for naval construction—by an act approved February 25, 1799, appropriating $200,000 for the purchase of growing or other timber, or of lands on which timber is growing suitable for the Navy, and for its preservation for future use. Small purchases were made on the Georgia coast, but nothing of importance beyond this was done until 1817, when, on March 1, another act was passed renewing the act of 1799, directing a reservation of such public lands, having a growth of live-oak or cedar timber suitable for the Navy, as might be selected by the President.

Under this act a reservation of 19,000 acres was made on Commissioners, Cypress, and Six islands, in Louisiana. Another appropriation of $10,000 was made in 1828, and some lands were purchased on Santa Rosa Sound, where during a few years an attempt at cultivation—clearing the ground of roots of other trees, sawing and transplanting and pruning—was made. This was done under the more general act of March 3, 1827, by which the President was authorized to take proper measures to preserve the live-oak timber growing on the lands of the United States. Provision was furthermore made, by an act approved March 2, 1831, for the punishment of persons cutting or destroying any live oak, red cedar, or other trees growing on any lands of the United States, by a fine of not less than thrice the value of the timber cut and imprisonment not exceeding twelve months.

Under these acts some 244,000 acres of forest land were reserved in Alabama, Florida, Louisiana, and Mississippi. (See Report on Forestry, Vol. I.)

It will be noted that no general conception of the need of a forest policy underlay these attempts at securing sufficient material for a special purpose; material of a kind which was not plentiful and was then believed a continued necessity for the building of war ships.

We can now smile at the concern expressed so early by writers in public prints with regard to the threatened exhaustion of forest supplies. The extent of our forest domain was then entirely unknown, and in the absence of railroad communication the location of supplies near the centers of civilization was of more moment. Logging then was carried on only along the coast and the Eastern river courses. Small country mills sawed to order for home consumption or sent material to the mouth of the river to be carried by vessel to home and foreign markets. The mills were run in the manner of the country gristmills, often in connection with them. This petty method of doing business lasted until the middle of this century, as is evidenced by the census of 1840, which reports 31,560 lumber mills, with a total product valued at $12,943,507, or a little over $400 per mill. By 1870 a change had already become apparent, when the product per mill was $6,500, which in 1890 had become $19,000, or about three times the value for 1870, with only 21,011 mills reported.

Besides the concentration of the lumber business into large establishments, which these figures show, there are other interesting changes indicated in the census figures, which we may briefly note here as having a bearing upon the question of the need of a forest policy and the cause for its development. While in 1890 the efficiency of the mill establishments had increased to three times what it was in 1870 and nearly fifty times that of 1840, the total product had also increased in the twenty years from 1870 to 1890, nearly three times. The capital employed in the lumber industry had increased four and one-third times, showing that, while capital became less efficient with concentration, the unit product of labor also became less efficient, in spite of the improvement in machinery. While every dollar of capital produced less result, by over 40 per cent in 1890, in the value of the product, every dollar of wages also produced less result, by over 12 per cent, than it did in 1870; but the cost of raw material had increased over 16 per cent. All these are signs of the deterioration and exhaustion of supplies.

It would be difficult to set a date or mark an event from which the change in the methods of the lumber industry, which is now such a stupendous factor in forest decimation, might be reckoned. It came as gradually or as fast as the railway systems expanded and made accessible the vast fields of supply in the Northwest, while the supplies of the East were being exhausted.

[1] Especially after the war the settlements of the West grew as if by magic; the railroad mileage more than doubled in the decade from 1865 to 1875, and with it the lumber industry developed

[1] See "American lumber," by B. E. Fernow, in One Hundred Years of American Commerce: D. O. Haynes Co., 1895.

by rapid strides into its modern methods and volume. In 1865 the State of New York still furnished more lumber than any other State; now it supplies only insignificant amounts.

In 1868 the golden age of lumbering had arrived in Michigan; in 1871 rafts filled the Wisconsin; in 1875 Eau Claire had 30, Marathon 30, and Fond du Lac 20 sawmills, now all gone; and mills at La Crosse, which were cutting millions of feet annually, are now closed. By 1882 the Saginaw Valley had reached the climax of its production, and the lumber industry of the great Northwest, with a cut of 8,000,000,000 feet of white pine alone, was in full blast. Southern development began much later to assume large proportions, but by the present time the lumber product of the Southern States has grown to proportions equal to those of the Northern States or the Great Lakes States, each of the three sections furnishing about equal shares in the enormous total cut.

No wonder that those observing this rapid decimation of our forest supplies and the incredible wastefulness and additional destruction by fire, with no attention to the aftergrowth, began again to sound the note of alarm. Besides the writings in the daily press and other non-official publications, we find the reports of the Department of Agriculture more and more frequently calling attention to the subject.

In the report issued by the Patent Office as early as 1849, we find the following significant language in a discussion on the influence of forests on water flow and their rapid destruction:

> The waste of valuable timber in the United States, to say nothing of firewood, will hardly begin to be appreciated until our population reaches 50,000,000. Then the folly and shortsightedness of this age will meet with a degree of censure and reproach not pleasant to contemplate.

The report for 1860 contains a long article by J. G. Cooper on "The forests and trees of northern America as connected with climate and agriculture."

In 1865 the Rev. Frederic Starr discussed fully and forcibly the "American forests, their destruction and preservation," in which, with truly prophetic vision, he says:

> It is feared it will be long, perhaps a full century, before the results at which we ought to aim as a nation will be realized by our whole country, to wit, that we should raise an adequate supply of wood and timber for all our wants. *The evils which are anticipated will probably increase upon us for thirty years to come with tenfold the rapidity with which restoring or ameliorating measures shall be adopted.*

And again:

> Like a cloud no bigger than a man's hand just rising from the sea, an awakening interest begins to come in sight on this subject, which as a question of political economy will place the interests of cotton, wool, coal, iron, meat, and even grain beneath its feet. Some of these, according to the demand, can be produced in a few days, others in a few months or in a few years, but timber in not less than one generation. The nation has slept because the gnawing of want has not awakened her. She has had plenty and to spare, but within thirty years she will be conscious that not only individual want is present, but that it comes to each from permanent national famine of wood.

The article is full of interesting detail, and may be said to be the starting basis for the campaign for better methods which followed.

Another unquestionably most influential official report was that upon Forests and Forestry of Germany, by Dr. John A. Warder, United States commissioner to the World's Fair at Vienna in 1873. Dr. Warder set forth clearly and correctly the methods employed abroad in the use of forests, and became himself one of the most prominent propagandists for their adoption in his own country. About the same time appeared the classical work of George P. Marsh, our minister to Italy, "The Earth as Modified by Human Action," in which the evil effects on cultural conditions of forest destruction were ably and forcibly pointed out.

The census of 1870 also for the first time attempted a canvass of our forest resources under Prof. F. W. Brewer, and the relatively small area of forest became known. All these publications had their influence in educating a larger number to a conception and consideration of the importance of the subject, so that when, in 1873, the committee on forestry of the American Association for the Advancement of Science was formed and presented its memorial to Congress, there existed already an intelligent audience, and, although a considerable amount of lethargy and lack of interest was exhibited, Congress could be persuaded, in 1876, to establish the agency

in the United States Department of Agriculture out of which grew the Division of Forestry, as described in the body of the report, a bureau of information on forestry matters.

While these were the beginnings of an official recognition of the subject by the Federal Government, private enterprise and the separate States started also about the same time to forward the movement. In 1867 the agricultural and horticultural societies of Wisconsin appointed a committee to report on the disastrous effects of forest destruction. In 1869 the Maine Board of Agriculture appointed a committee to report on a forest policy for the State, leading to the act of 1872 "for the encouragement of the growth of trees," exempting from taxation for twenty years lands planted to trees, which law, as far as we know, remained without result. About the same time a real wave of enthusiasm with regard to planting of timber seems to have pervaded the country, and especially the Western prairie States. In addition to laws regarding the planting of trees on highways, laws for the encouragement of timber planting, either under bounty or exemption from taxation, were passed in Iowa, Kansas, and Wisconsin in 1868, in Nebraska and in New York in 1869, in Missouri in 1870, in Minnesota in 1871, in Iowa in 1872, in Illinois in 1874, in Nevada, Dakota, and Connecticut in 1872, and finally the Federal Government joined in this kind of legislation by the so-called timber-culture acts of 1873 and 1874, amended in 1876 and 1877.

For the most part these laws remained a dead letter. The encouragement by release from taxes, except in the case of the Federal Government, was not much of an inducement, nor does the bounty provision seem to have had greater success, except in taking money out of the treasuries. Finally these laws were in many cases repealed.

The timber-culture act was passed by Congress on March 3, 1873, by which the planting of timber on 40 acres of land, or a proportionate area in the treeless territory, conferred the title to 160 acres or a proportionate amount of the public domain. This law had not been in existence ten years when its repeal was demanded, and this was finally secured in 1891, the reason being that, partly owing to the crude provisions of the law and partly to the lack of proper supervision, it had been abused and had given rise to much fraud in obtaining title to lands under false pretenses. It is difficut to say how much impetus the law gave to bona fide forest planting and how much timber-growth has resulted from it. Unfavorable climate, lack of satisfactory plant material, and lack of knowledge as to proper methods led to many failures. In 1889 the Division of Forestry made an analysis of the figures furnished by the General Land Office, which shows that 38,080,506 acres were entered under the timber-culture act up to June 30, 1888. This should represent a planted area of 2,380,030 acres if the law were complied with and the entries not changed. Allowing ten years for timber-claim planters to prove up their entries (the law places it at eight years, allowing extensions on account of failures), the entries of the first six years, 1873 to 1878, alone give us some points of comparison for the estimation of results. During that time 3,821,843 acres had been entered, representing a supposed area of less than 50,000 acres planted to timber.

But in 1888, ten years later, the acreage proved up was only 779,582 acres, or about 20 per cent of the land entered, representing perhaps 175,000 acres planted, if the original plantations persisted.

From this it would appear that the timber-culture act has been a failure so far as the creating of forests is concerned.

It is asserted that a better percentage will be obtained from the entries of later years, because more experience has been gained, and timber-claim planting was done under contract by persons who make a business of it. Yet the consensus of unbiased testimony goes to show that timber-claim planting, as a rule, did not produce the results sought after, and has mostly been used as a means for speculation in Government lands, partly with that design from the beginning, partly as a necessity after failure to obtain the land by timber planting.

There is also considerable planting of wind-breaks and groves done on homesteads, which is said to be attended with better results. Altogether, however, the amount of tree planting is infinitesimal, if compared with what is necessary for climatic amelioration; and it may be admitted, now as well as later, that the reforestation of the plains must be a matter of cooperative if not of national enterprise.

Original and final entries under timber-culture acts until 1888.

State or Territory.	Original entries.		Final entries.	
	No.	*Acres.*	*No.*	*Acres.*
Arizona	856	122,570	4	640
Arkansas	39	4,416		
California	6,671	856,076	7	889
Colorado	23,650	3,498,351	18	2,278
Dakota	63,647	11,500,026	1,306	185,064
Idaho	3,257	427,017	15	1,711
Iowa	931	75,514	124	11,505
Kansas	58,183	8,738,944	1,544	206,146
Louisiana	672	96,342		
Minnesota	14,377	1,882,030	781	104,758
Montana	2,555	339,998	4	479
Nebraska	48,589	7,780,825	1,753	237,657
Nevada	42	5,879		
New Mexico	1,059	146,928	3	326
Oregon	6,128	908,248	47	6,796
Utah	1,048	128,188	6	660
Washington	7,673	1,114,761	194	20,673
Wyoming	2,401	454,393		
Total	241,778	38,080,506	5,806	779,582

Private interest of homesteaders and settlers without these aids has probably been as effective. In this direction the establishment of arbor days throughout the States has been a stimulating influence. From its inception by Governor J. Sterling Morton and first inauguration by the State board of agriculture of Nebraska in 1872, it has become a day of observance in nearly every State, until its adoption as a national holiday may be shortly expected.

While with the exception of the so-called treeless States, perhaps not much planting of economic value is done, the observance of the day in schools as one set apart for the discussion of the importance of trees, forests, and forestry, has been productive of an increased interest in the subject.

To be sure, arbor days have had also a retarding influence upon the practical forestry movement in leading people into the misconception that forestry consists in tree planting, in diverting attention from the economic question of the proper use of existing forest areas, in bringing into the discussion poetry and emotions, which have clouded the hardheaded practical issues and delayed the earnest attention of practical business men.

The following table exhibits the condition of the Arbor-day movement at the present time:

Arbor-day observance in the United States.

States and Territories.	First observed.		When legally established.	Legal holiday.	Date of annual observance.	By whom fixed.
	Date.	By whose appointment.				
Alabama	1887	Superintendent of education			February 22	
Arizona	1890-91	Legislature	1891	Yes	First Friday after February 1.	Legislature.
Arkansas						
California	1886	General Howard and others			Variable	
Colorado	1885	Governor	1889	For schools	Third Friday in April.	Do.
Connecticut	1887	do	1886		In spring	Governor.
Florida	1886	do			January 8	Do.
Georgia	1891	Legislature	1890	For schools	First Friday in December.	Legislature.
Idaho	1887	do	1887	Yes	Last Monday in April.	Do.
Illinois	1888	do	1887			Governor.
Indiana	1884	Superintendent of public instruction			October, usually	Superintendent of public instruction.
Indian Territory						
Iowa	1887	Superintendent of public instruction			Variable	Do.
Kansas	1875	Mayor of Topeka			April, usually	Governor.
Kentucky	1886	Legislature	1886			Do.
Louisiana	1888-89	State superintendent of schools			Option of parish boards.	
Maine	1887	Legislature	1887			Do.
Maryland	1889	do	1884		April	Do.
Massachusetts	1886	Village Improvement Society	1886		Last Saturday in April.	Legislature.
Michigan	1876	Governor	1885			Governor.
Minnesota	1876	State Forestry Association				Do.
Mississippi	1892	State board of education	1892			State board of education.
Missouri	1886	Superintendent of schools	1889	For schools	First Friday after First Tuesday in April.	Legislature.
Montana	1887	Legislature	1887		Third Tuesday in April	Do.
Nebraska	1872	Board of agriculture	1885	Yes	April 22	Do.
Nevada	1887	Legislature	1887	For schools		Governor.
New Hampshire	1886	do	1885			Do.
New Jersey	1884	do	1884		April	Do.

Arbor-day observance in the United States—Continued.

States and Territories.	First observed.		When legally established.	Legal holiday.	Date of annual observance.	By whom fixed.
	Date.	By whose appointment.				
New Mexico	1890	Legislature	1891	For schools	Second Friday in March.	Legislature.
New York	1889	do	1888		First Friday after May 1.	Do.
North Carolina	1893	do	1893			Do.
North Dakota	1884	Governor			May	Governor.
Ohio	1882	do	1882		April	Do.
Oklahoma	1892	Superintendent of public instruction			February 22	Superintendent of public instruction.
Oregon	1889	Legislature	1889		Second Friday in April	Legislature.
Pennsylvania	1887	do	1887			Governor.
Rhode Island	1887	do	1886		Variable	Do.
South Carolina	(*a*)	Individual action				
South Dakota	1884	Governor				Do.
Tennessee	1875	Normal College	1887		November	County superintendent.
Texas	1890	Legislature	1889	Yes	February 22	Legislature.
Utah	1892	do	1892	Yes	First Saturday in April	Do.
Vermont	1885	Governor				Governor.
Virginia	1892	Village Improvement Society				
Washington	1892	Agricultural College				
West Virginia	1883	Superintendent of public instruction			Fall and spring	Superintendent of schools.
Wisconsin	1889	Legislature	1889			Governor.
Wyoming	1888	do	1888	Yes		Do.

a Uncertain.

Private efforts in the East in the way of fostering and carrying on economic timber planting should not be forgotten, such as the prizes offered by the Society for the Promotion of Agriculture, the planting done by the private landholders at Cape Cod, in Rhode Island, Virginia, and elsewhere. Altogether, however, these efforts have been sporadic and unsystematic, and not on any scale commensurate with the destruction of virgin forest resources.

ASSOCIATED PROPAGANDA.

The first forestry association organized for the purpose of advancing forestry interests was formed on January 12, 1876, in St. Paul, Minn., largely through the efforts of Leonard B. Hodges. This association was aided by State appropriations, which enabled it to offer premiums for the setting out of plantations, and also to publish and distribute widely a Tree Planters' Manual. Revised editions are issued from time to time, and a distribution of plant material is also occasionally attempted, the State aiding to the extent of $1,000 to $2,000 annually.

In 1875 Dr. John A. Warder issued a call for a convention in Chicago to form a national forestry association. This association was completed in 1876 at Philadelphia, but never showed any life or growth.

In 1882 a number of patriotic citizens at Cincinnati called together a forestry congress, incited thereto by the visit and representations of Baron von Steuben, a Prussian forest official, when visiting this country on the occasion of the centennial celebration of the surrender of Yorktown.

A very enthusiastic and representative gathering, on April 25, was the result, lasting through the week, which led to the formation of the American Forestry Association. This association, holding yearly and intermediate meetings in different parts of the States, has become the center of all private efforts to advance the forestry movement. Twelve volumes of its proceedings contain not only the history of progress in establishing a forest policy, but also much other information of value on forestry subjects. It now publishes a monthly journal, The Forester. It is unaided by government, its efforts being entirely borne by private means and the annual dues of its membership, its officers doing gratuitous work. It has been especially instrumental in bringing about the establishment of the Federal forest reservation policy, which we will note further on in detail.

Other local or State forestry associations were formed more or less under the lead of the national association, and exist now in Maine, Massachusetts, Connecticut, New York, Pennsylvania, New Jersey, North Carolina, South Carolina, Ohio, Wisconsin, Minnesota, Dakota, Colorado, and Washington, while several other societies, like the Sierra Nevada Club and the Mazamas of

the Pacific coast, and State horticultural societies in various States, make the subject one to be discussed and to be fostered.

The most active of these associations, publishing also, since its formation in 1886, a bimonthly journal, Forest Leaves (at first less frequently), is the Pennsylvania State Forestry Association, which has succeeded in thoroughly committing its State to a proper forest policy, as far as official recognition is concerned.

FORESTRY COMMISSIONS.

Usually as a result of this associated private effort various States have appointed forestry commissions or commissioners. These commissions were at first for the most part instituted for inquiry and to make a report, upon which a forest policy for the State might be framed. Others have become permanent parts of the State organization with executive or educational functions. Such commissions of inquiry were appointed at various times in Maine, New Hampshire, Vermont, Massachusetts, New York, New Jersey, Pennsylvania, North Carolina, Ohio, Michigan, Wisconsin, North Dakota, Colorado, California; while commissioners or commissions with executive duties exist now or did exist for a time in Maine, New Hampshire, New York, Pennsylvania, Wisconsin, Minnesota, Colorado, and California.

Maine has an efficient forest-fire law (chap. 26 of Revised Statutes) based on that of the State of New York, and a forest commissioner (created in 1891, Public Laws, chap. 100)—the State land agent of the State being ex officio designated as such—to look to its execution. The forest commissioner has in addition annually a small amount of money appropriated to satisfy the requirements of the following two sections of the law:

SEC. 15. The forest commissioner shall take such measures as the State superintendent of public schools and the president of the State college of agriculture and the mechanic arts may approve for awakening an interest in behalf of forestry in the public schools, academies, and colleges of the State, and of imparting some degree of elementary instruction upon this subject therein.

SEC. 16. The forest commissioner shall prepare tracts or circulars of information, giving plain and concise advice for the care of wood lands and for the preservation of forest growth. These publications shall be furnished to any citizen of the State upon application.

Two very interesting and instructive reports on the growth of the spruce and on allied subjects are the result.

New Hampshire had a temporary commission of inquiry, appointed in 1881 and reporting in 1885; and another such commission in 1889, reporting in 1893, when the permanent forestry commission was created (March 29, 1893) with a paid secretary, who publishes an annual report. The main function of the commission is one of inquiry and suggestion, besides partial supervision of the forest-fire law. The acquisition of public parks, if private munificence should be found willing to furnish the necessary funds, is also made a part of the function of the commission. Two small areas have been donated.

In Massachusetts no special public officers are charged with the care of forestry interests, and hence the otherwise useful legislation is probably of only partial effect. Its best feature is perhaps that of encouraging communities to become owners of forest tracts (chap. 255, acts of 1882). The city of Boston has made special efforts in this direction, having set aside more than 7,000 acres for forest parks. The State board of agriculture was, in 1890, ordered to inquire "into the consideration of the forests of the State, the need and methods of their protection," and report thereon, which order did not produce anything of value. A bill to secure such forest survey, introduced into the legislature in the year 1897, failed of passage.

In Vermont a commission of inquiry was instituted in 1882, reporting in 1884 without any practical result, the proposed legislation remaining unconsidered.

In New York a law was passed in 1872 naming seven citizens, with Horatio Seymour, chairman, as a State park commission, instructed to make inquiries with the view of reserving or appropriating the wild lands lying northward of the Mohawk or so much thereof as might be deemed expedient, for a State park. The commission, finding that the State then owned only 40,000 acres in that region, and that there was a tendency on the part of the holders of the rest to combine for the enhancement of values should the State want to buy, recommended a law forbidding further sales of State lands and their retention when forfeited for the nonpayment of taxes.

It was eleven years later, in 1883, that this recommendation was acted upon, when the State through the nonpayment of taxes by the owners had become possessed of 600,000 acres.

In 1884 the comptroller was authorized to employ "such experts as he may deem necessary to investigate and report a system of forest preservation." The report of a commission of four members was made in 1885, but the legislation proposed was antagonized by the lumbering interests. The legislature finally passed a compromise bill entitled "An act establishing a forest commission, and to define its powers, and for the preservation of forests."

This legislation, afterward amended, is the most comprehensive of that of any State in the Union.

The original forest commission, appointed under the act of May 15, 1885, was superseded in 1895 by the commission of fisheries, game, and forests, under the law of April 25, 1895. This law is a comprehensive measure in which allied interests are brought under the control of a single board. Under this law the commission consists of five members appointed by the governor with consent of the senate, the term of office being five years. The president, who is designated as such by the governor, receives a salary of $5,000 per year and traveling expenses, and devotes all his time to the work of his office. The remaining four commissioners each receive $1,000 per year and traveling expenses. The board holds at least four meetings on designated days each year. It has a secretary at $2,000 per year, and necessary clerical force. The duties of the board are to propagate and distribute food, fish, and game; to enforce all laws for the protection of fish and game, and for the protection and preservation of the forest reserve. It has full control of the Adirondack Park and forest reserve, and is authorized to make rules for its care and safety.

The commission appoints thirty-five "fish and game protectors and foresters" (hereafter called foresters), one of whom is to be known as chief, and two others as his assistants, the chief to have direction and control of the entire force. The foresters give bonds for the proper discharge of their duty. The chief forester receives $2,000 per year and traveling expenses; the assistant foresters $1,200 each; and the remaining foresters $500 each: all have an extra allowance for traveling expenses and each of them receives one-half of all fines collected in actions brought upon information furnished by them. It is their duty to enforce all laws and regulations of the commission for the protection of fish and game and for the protection and preservation of the forest reserve and all rules and regulations for the care of the Adirondack Park. They have full power to execute all warrants and search warrants and to serve subpœnas.

Each forester keeps a record of his official acts and reports a summary of it, with important details, monthly to his chief. The monthly payment of salary is contingent upon the receipt of this report. The chief forester reports to the commission all cases of neglect of duty or negligence on the part of the foresters, and he also makes a monthly report of the operations of his department.

The commission may, in its discretion, appoint or remove special foresters recommended by any board of supervisors, but such special foresters receive no compensation from the State. All peace officers have the same powers as foresters in the enforcement of the fisheries, game, and forest law.

Article XII, chapter 395, Laws of 1895, describes the forest preserve (sec. 270), and defines the powers and duties of the commission (sec. 271), whose duty it is to (1) have the care, custody, control, and superintendence of the forest preserve; (2) maintain, protect, and promote the growth of the forests in the preserve; (3) have charge of the public interests of the State in regard to forestry and tree planting, and especially with reference to forest fires in every part of the State; (4) possess all the powers relating to the preserve which were vested in the commissioners of the land office and in the comptroller on May 15, 1885; (5) prescribe rules and regulations affecting the whole or any part of the preserve for its use, care, and administration, and alter or amend the same; but neither such rules or regulations nor anything contained in this article shall prevent or operate to prevent the free use of any road, stream, or water as the same may have been heretofore used, or as may be reasonably required in the prosecution of any lawful business; (6) take measures for the awakening of an interest in forestry in the schools and the imparting of elementary instruction on such subject therein, and issue tracts and circulars for the care of private woodlands, etc.; (7) print and post rules for the prevention and suppression of forest fires.

Section 272 provides that all income from the State forest lands, including receipts for trespasses, shall be paid into the State treasury and constitute a fund for the purchase of lands within the Adirondack Park. The comptroller shall audit the accounts of the board, and an annual report of all its doings shall be made in January of each year. Section 273 provides for the division of lands within the forest preserve in which the State owns an undivided interest, with individuals. Section 274 provides for the taxation of the forest preserve. All wild or forest land within the forest preserve shall be assessed and taxed at a like valuation and rate as similar lands of individuals within the counties where situated. The assessors shall file with the commission and the comptroller a copy of the assessment roll of their towns, and shall state (under oath) which and how much of the lands assessed are forest lands and which are lands belonging to the State. The comptroller, after hearings, shall "correct or reduce any assessment of State land which may be, in his judgment, an unfair proportion to the remaining assessment of land within the town," and shall otherwise approve the assessment. No such assessment shall be valid without the approval of the comptroller. No tax for the erection of schoolhouses or road opening shall be valid unless such erection or opening is first approved by the board. Payment of taxes on State lands shall be made by the State treasurer crediting the county treasurer with the amount of such taxes due on such lands payable on the State tax of the year. Sections 275–279 and 281 provide for protection against fire, with penalties for violation of same. Section 280 provides for actions for trespasses upon the forest preserve. In addition to authorizing the board to bring suits for trespass on the lands of the forest preserve the same as a citizen may bring for trespass on private lands, it makes the cutting of trees or removal of any tree, timber, or bark from any portion of the preserve a misdemeanor, punishable by a fine of $25 for every tree so cut or removed. The board is empowered to employ attorneys, with the consent of the attorney-general and comptroller, to prosecute offenders against this act, and such offenders may be arrested without warrant (sec. 282).

Article XIII refers to the Adirondack Park; section 290 defines its limits and adds: "Such park shall be forever reserved, maintained, and cared for as ground open to the free use of all the people for their health and pleasure, and as forest lands, necessary to the preservation of the headwaters of the chief rivers of the State, and a future timber supply; and shall remain part of the forest preserve."

The park is placed in the control and custody of the board of fisheries, game, and forest, which is empowered (1) to contract for the purchase of land within the limits of the park; (2) to contract with owners of land situated within the park limits that such lands may become part of the park and subject to the provisions of this article in consideration of the exemption of such lands from taxation for State and county purposes, provided that the owners or their grantors shall refrain forever from removing any timber except spruce, tamarack, or poplar, 12 inches in diameter at three feet from the ground, or fallen, burned, or blighted timber, and obey such other conditions of occupancy as may be equitable. Owners may also clear land for agricultural or domestic purposes, at the rate of not more than 1 acre within the boundary of each 100 acres covered by such contract; (3) to prescribe and enforce rules for the licensing or regulation of guides and other persons engaged in business therein; (4) to lay out roads and paths in the park.

Contracts mentioned in this article require the approval of the commissioners of the land office, and every conveyance mentioned in this article shall be certified by the attorney-general to be in conformity with the contract, and approved by him as to form before acceptance or delivery. The law further provides that the board include in its annual report an account of its proceedings with reference to the park.

The legislature of 1897 passed the following important act (approved April 8, 1897), which is quoted entire:

AN ACT to provide for the acquisition of land in the territory embraced in the Adirondack Park, and making an appropriation therefor.

The people of the State of New York, represented in senate and assembly, do enact as follows:

SECTION 1. The governor, within twenty days after this act takes effect, shall appoint from the commissioners of fisheries, game, and forest, and the commissioners of the land office, by and with the advice and consent of the senate, three persons to constitute a board to be known as "the forest preserve board." The members of such board may be removed by the governor at his pleasure. Vacancies shall be filled in like manner as an original appointment. The members of the board shall not receive any compensation for their services under this act, but

shall receive their actual and necessary expenses, to be audited by the comptroller. The board may employ such clerical and other assistants as it may deem necessary. The forest preserve board annually in the month of January shall make a written report to the governor showing in detail all its transactions under this act during the preceding calendar year.

SEC. 2. It shall be the duty of the forest preserve board, and it is hereby authorized, to acquire for the State, by purchase or otherwise, land, structures, or waters, or such portion thereof in the territory embraced in the Adirondack Park, as defined and limited by the fisheries, game, and forest law, as it may deem advisable for the interests of the State.

SEC. 3. The forest preserve board may enter on and take possession of any land, structures, and waters in the territory embraced in the Adirondack Park, the appropriation of which in its judgment shall be necessary for the purposes specified in section two hundred and ninety of the fisheries, game, and forest law, and in section seven of article seven of the constitution.

SEC. 4. Upon the request of the forest preserve board an accurate description of such lands so to be appropriated shall be made by the State engineer and surveyor, or the superintendent of the State land survey, and certified by him to be correct, and such board or a majority thereof shall indorse on such description a certificate stating that the lands described therein have been appropriated by the State for the purpose of making them a part of the Adirondack Park; and such description and certificate shall be filed in the office of the secretary of state. The forest preserve board shall thereupon serve on the owner of any real property so appropriated a notice of the filing and the date of filing of such description containing a general description of the real property belonging to such owner which has been so appropriated; and from the time of such service the entry upon and appropriation by the State of the real property described in such notice for the uses and purposes above specified shall be deemed complete, and thereupon such property shall be deemed and be the property of the State. Such notice shall be conclusive evidence of an entry and appropriation by the State. The forest preserve board may cause duplicates of such notice with an affidavit of due service thereof on such owner to be recorded in the books used for recording deeds in the office of the clerk of any county of this State where any of the property described therein may be situated, and the record of such notice and such proof of service shall be evidence of the due service thereof.

SEC. 5. Claims for the value of the property taken and for damages caused by any such appropriation may be adjusted by the forest preserve board if the amount thereof can be agreed upon with the owners of the land appropriated. The board may enter into an agreement with the owner of any land so taken and appropriated for the value thereof and for any damages resulting from such appropriation. Upon making such agreement the board shall deliver to the owner a certificate stating the amount due to him on account of such appropriation of his lands, and a duplicate of such certificate shall also be delivered to the comptroller. The amount so fixed shall be paid by the treasurer upon the warrant of the comptroller.

SEC. 6. If the forest preserve board is unable to agree with the owner for the value of the property so taken or appropriated, or on the amount of damages resulting therefrom, such owner, within two years after the service upon him of the notice of appropriation as above specified, may present to the court of claims a claim for the value of such land and for such damages, and the court of claims shall have jurisdiction to hear and determine such claim and render judgment thereon. Upon filing in the office of the comptroller a certified copy of the final judgment of the court of claims, and a certificate of the attorney-general that no appeal from such judgment has been or will be taken by the State, or, if an appeal has been taken, a certified copy of the final judgment of the appellate court, affirming in whole or in part the judgment of the court of claims, the comptroller shall issue his warrant for the payment of the amount due the claimant by such judgment, with interest from the date of the judgment until the thirtieth day after the entry of such final judgment, and such amount shall be paid by the treasurer.

SEC. 7. The owner of land to be taken under this act may, at his option, within the limitations hereinafter prescribed, reserve the spruce timber thereon ten inches or more in diameter at a height of three feet above the ground. Such option must be exercised within six months after the service upon him of a notice of the appropriation of such land by the forest preserve board, by serving upon such board a written notice that he elects to reserve the spruce timber thereon. If such a notice be not served by the owner within the time above specified, he shall be deemed to have waived his right to such reservation, and such timber shall thereupon become and be the property of the State. In case land is acquired by purchase, the spruce timber and no other may be reserved by agreement between the board and the owner, subject to all the provisions of this act in relation to timber reserved after an appropriation of land by the forest preserve board. The presentation of a claim to the court of claims before the service of a notice of reservation shall be deemed a waiver of the right to such reservation.

SEC. 8. The reservation of timber and the manner of exercising and consummating such right are subject to the following restrictions, limitations, and conditions:

1. The reservation does not include or affect timber within twenty rods of a lake, pond, or river, and such timber can not be reserved. Roads may be cut or built across or through such reserved space of twenty rods, under the supervision of the forest preserve board, for the purpose of removing spruce timber from adjoining land, and the reservation of spruce timber within such space shall be deemed a reservation by the owner, his assignee, or representative, of the right to cut other timber necessary in constructing such road, but such reservation does not confer a right to remove such other timber so cut, or to use it otherwise than in constructing a road.

2. The timber reserved must be removed from the land within fifteen years after the service of notice of reservation, or the making of an agreement subject to regulations to be prescribed by the forest preserve board; but such land shall not be cut over more than once, and the said board may prescribe regulations for the purpose of enforcing this limitation. All timber reserved and not removed from the land within such time shall thereupon

become and be the property of the State, and all the title or claim thereto by the original owner, his assigns or representatives, shall thereupon be deemed abandoned.

SEC. 9. A person who reserves timber as herein provided is not entitled to any compensation for the value of the land purchased or taken and appropriated by the State, nor for any damages caused thereby, until:

1. The timber so reserved is all removed and the object of the reservation fully consummated; or

2. The time limited for the removal of such timber has fully elapsed, or the right to remove any more timber is waived by a written instrument filed with the forest preserve board; and

3. The forest preserve board is satisfied that no trespass on State lands has been committed by such owner or his assigns or representatives; that no timber or other property of the State not so reserved has been taken, removed, destroyed, or injured by him or them, and that a cause of action in behalf of the State does not exist against him or them for any alleged trespass or other injury to the property or interests of the State; and

4. That the owner, his assignee, or other representative has fully complied with all rules, regulations, and requirements of the forest preserve board concerning the use of streams or other property of the State for the purpose of removing such timber.

SEC. 10. A warrant shall not be drawn by the comptroller for the amount of compensation agreed upon between the owner and the forest preserve board, nor for the amount of a judgment rendered by the court of claims, until a further certificate by the board is filed with him to the effect that the owner has not reserved any timber or that he, his assignee, or other representative, has complied with the provisions of this act, or has otherwise become entitled to receive the amount of the purchase price, award, or judgment.

SEC. 11. The forest preserve board may settle and adjust any claims for damages due to the State on account of any trespasses or other injuries to property or interests of the State, or penalties incurred by reason of such trespasses or otherwise, and the amount of such damages or penalties so adjusted shall be deducted from the original compensation agreed to be paid for the lands, or for damages, or from a judgment rendered by the court of claims on account of the appropriation of such land. A judgment recovered by the State for such a trespass or for a penalty shall likewise be deducted from the amount of such compensation or judgment.

SEC. 12. If timber is reserved upon land purchased or appropriated as provided by this act, interest is not payable upon the purchase price or the compensation which may be awarded for the value of such land or for damages caused by such appropriation, except as provided in section six.

SEC. 13. Persons entitled to cut and remove timber under this act may use streams or other waters belonging to the State within the forest preserve for the purpose of removing such timber, under such regulations and conditions as may be prescribed or imposed by the forest preserve board. The persons using such waters shall be liable for all damages caused by such use.

SEC. 14. If timber be reserved, its value at the time of making an agreement between the owner and the forest preserve board for the value of the land so appropriated and the damages caused thereby, or at the time of the presentation to the court of claims of a claim for such value and damages, shall be taken into consideration in determining the compensation to be awarded to the owner on account of such appropriation either by such agreement or by the judgment rendered upon such a claim.

SEC. 15. The forest preserve board may appoint inspectors to examine the lands upon which timber is reserved and ascertain and report to the board, from time to time, or whenever required, whether such timber is being removed in accordance with the provisions of this act, whether any trespasses or other violations of this act are being committed, and whether the persons entitled to the use of such waters for the purpose of removing timber have complied with the regulations and conditions relating thereto prescribed or imposed by the board.

SEC. 16. The forest preserve board shall fix the compensation of all clerks, inspectors, or other assistants employed by it, which compensation shall be paid by the treasurer, upon the certificate of the board and the audit and warrant of the comptroller. A person so appointed may be removed at the pleasure of the board.

SEC. 17. The forest preserve board shall take such measures as may be necessary or proper to perfect the title to any lands in the forest preserve now held by the State, and for that purpose may pay and discharge any valid lien or incumbrance upon such land, or may acquire any outstanding or apparent right, title, claim, or interest which, in its judgment, constitutes a cloud on such title. The amounts necessary for the purpose of this section shall be paid by the treasurer upon the certificate of the board and the audit and warrant of the comptroller.

SEC. 18. If an offer is made by the forest preserve board for the value of land appropriated, or for damages caused by such appropriation, and such offer is not accepted, and the recovery in the court of claims exceeds the offer, the claimant is entitled to costs and disbursements as in an action in the supreme court, which shall be allowed and taxed by the court of claims and included in its judgment. If in such a case the recovery in the court of claims does not exceed the offer, costs, and disbursements to be taxed shall be awarded in favor of the State against the claimant and deducted from the amount awarded to him, or if no amount is awarded judgment shall be entered in favor of the State against the claimant for such costs and disbursements. If an offer is not accepted, it can not be given in evidence on the trial.

SEC. 19. When a judgment for damages is rendered for the appropriation of any lands or waters for the purposes specified in this act, and it appears that there is any lien or incumbrance upon the property so appropriated, the amount of such lien shall be stated in the judgment, and the comptroller may deposit the amount awarded to the claimant in any bank in which moneys belonging to the State may be deposited to the account of such judgment, to be paid and distributed to the persons entitled to the same as directed by the judgment.

SEC. 20. If a person cuts down or carries off any wood, bark, underwood, trees, or timber, or any part thereof, or girdles or otherwise despoils a tree in the forest preserve, without the permission of the forest preserve board, an action may be maintained against him by the board in its name of office and in such an action the board may recover

treble damages if demanded in the complaint. Every such person also forfeits to the State the sum of twenty-five dollars for every tree cut down or carried away by him or under his direction, to be recovered in a like action by the forest preserve board. All sums recovered in any such action shall be paid by the board to the State treasurer and credited to the general fund.

SEC. 21. Service of a notice by the forest preserve board under section four must be personal if the person to be served can be found in the State. The provisions of the code of civil procedure relating to the service of a summons in an action in the supreme court, except as to publication, apply, so far as practicable, to the service of such a notice. If a person to be served can not with due diligence be found in the State, a justice of the supreme court may, by order, direct the manner of such service, and service shall be made accordingly.

SEC. 22. The court of claims, if requested by the claimant or the attorney-general, shall examine the real property affected by the claim and take the testimony in relation thereto in the county where such property or part thereof is situated. The actual and necessary expenses of such judge and of each officer of the court in making such examination and in so taking testimony shall be audited by the comptroller and paid from the money appropriated for the purposes of this act.

SEC. 23. The power to appropriate real property, vested in the forest preserve board by section four, is subject to the following limitations: Such real property must adjoin land already owned or appropriated by the State at the time the description and certificate are filed in the office of the secretary of state, except that timber land not so adjoining State land may be appropriated whenever in the judgment of the board timber thereon other than spruce, pine, or hemlock is being cut or removed to the detriment of the forest or the interests of the State.

SEC. 24. The sum of six hundred thousand dollars, or so much thereof as may be necessary, is hereby appropriated for the purposes specified in this act, out of any moneys in the treasury not otherwise appropriated. In addition to the amount above appropriated, the comptroller, upon the written request of the forest preserve board, is hereby authorized and directed to borrow, from time to time, not exceeding in the aggregate the sum of four hundred thousand dollars for the purposes specified in this act, and to issue bonds or certificates therefor payable within ten years from their date, bearing interest at a rate not exceeding five per centum per annum, and which shall not be sold at less than par. The sums so borrowed are hereby appropriated, payable out of the moneys realized from the sale of such bonds or certificates, to be expended under the direction of the forest preserve board for the purposes of this act, and to be paid by the treasurer on the warrant of the comptroller.

SEC. 25. All acts and parts of acts inconsistent with this act are hereby repealed.

SEC. 26. This act shall take effect immediately.

Under this act the State spent last year $1,000,000 in purchasing forest lands to the amount of over 250,000 acres, so that the total holdings comprise now over 1,000,000 acres; and during the present year (1898) another half million dollars is being disbursed for the same purpose.

In New Jersey the appropriations for the State geological survey have since 1894 contained a clause which provides that the State geologist shall make (1) a survey to ascertain the extent, location, and character of the wild lands or forest lands of the State, and the advantages of their retention in forestry; (2) a survey of the more important watersheds or drainage basins and their forested areas, with reference to the protective measures needed to save this forest cover and thereby maintain the purity of the water, as well as promote the more equable flow of the streams; (3) a study of the relations of forests as climatic factors, and particularly to the rainfall; (4) a compilation of the forest legislation in other States and countries in so far as it may be applicable to conditions in New Jersey.

Two reports have been published discussing forest conditions in various parts of the State, effects of forest fires, relation of forests to stream-flow, etc.

In Pennsylvania, through the efforts of the State forestry association, a commission of inquiry was first created by the following act on May 23, 1893:

AN ACT relative to a forestry commission.

Be it enacted, etc.:

SECTION 1. That the governor be authorized to appoint two persons as a commission, one of whom is to be a competent engineer, one a botanist, practically acquainted with the forest trees of the Commonwealth, whose duty it shall be to examine and report upon the conditions of the slopes and summits of the important watersheds of the State, for the purpose of determining how far the presence or absence of the forest cover may be influential in producing high and low-water stages in the various river basins; and to report how much timber remains standing of such kinds as have special commercial value, how much there is of each kind; as well, also, as to indicate the part or parts of the State where each grows naturally, and what measures, if any, are being taken to secure a supply of timber for the future. It shall further be the duty of said commission to suggest such measures in this connection as have been found of practical service elsewhere in maintaining a proper timber supply, and to ascertain, as nearly as practicable, what proportion of the State not now recognized as mineral land is unfit for remunerative agriculture and could with advantage be devoted to the growth of trees.

SEC. 2. The said commission shall also ascertain what wild lands, if any, now belong to the Commonwealth, their extent, character, and location, and report the same, together with a statement of what part or parts of such

lands would be suitable for a State forest reserve; and further, should the lands belonging to the Commonwealth be insufficient for such purpose, then to ascertain and report what other suitable lands there may be within the State, their extent, character, and value. The final report of the said commission shall be presented to the legislature not later than March 15, 1895.

SEC. 3. The said commission shall have power to appoint one competent person to act as statistician, whose duty it shall be to compile the statistics collected by said commission, under their direction and supervision, whose salary shall be one thousand dollars per annum, with necessary expenses, to be paid in the same manner as is hereinafter provided for the payment of the forestry commission.

SEC. 4. The commissioners appointed hereunder shall be entitled to receive by quarterly payments a compensation as follows: The engineer, twenty-five hundred dollars ($2,500) per annum; the botanist, twenty-five hundred dollars ($2,500) per annum, with necessary expenses; and the sum of twenty thousand dollars ($20,000) is hereby appropriated out of any money in the Treasury not otherwise appropriated, to be paid by warrant drawn by the auditor-general.

Before the report of this commission was published the legislature of 1895 provided for an executive department of agriculture, and included in its organization a provision for a division of forestry, the botanist member of the previous commission, Dr. J. T. Rothrock, being appointed commissioner of forestry:

The law creating a department of agriculture was approved by the governor March 13, 1895. The chapters referring to forestry are as follows:

Be it enacted by the senate and house of representatives of the Commonwealth of Pennsylvania in general assembly met, and it is hereby enacted by authority of the same:

SECTION 1. That there be, and hereby is, established a department of agriculture, to be organized and administered by an officer who shall be known as the secretary of agriculture, who shall be appointed by the governor, by and with the advice and consent of the senate, for the term of four years, at an annual salary of three thousand five hundred dollars, and who, before entering upon the duties of his office, shall take and subscribe the oath prescribed in article seven of the constitution. Said secretary shall be ex officio secretary of the State board of agriculture, and shall succeed to all the powers and duties now conferred by law upon the secretary of said board.

SEC. 2. That it shall be the duty of the secretary of agriculture, in such ways as he may deem fit and proper to encourage and promote the development of agriculture, horticulture, forestry, and kindred industries, to collect and publish statistics and other information in regard to the agricultural industries and interests of the State. * * * In the performance of the duties prescribed by this act the secretary of agriculture shall, as far as practicable, * * * enlist the aid of the State geological survey for the purpose of obtaining and publishing useful information respecting the economical relations of geology to agriculture, forestry, and kindred industries. He shall make an annual report to the governor, and shall publish from time to time such bulletins of information as he may deem useful and advisable. Said report and bulletins shall be printed by the State printer in the same manner as other public documents, not exceeding five thousand copies of any one bulletin.

SEC. 3. That it shall be the duty of the secretary to obtain and publish information respecting the extent and condition of forest lands in this State, to make and carry out rules and regulations for the enforcement of all laws designed to protect forests from fires and from all illegal depredations and destruction, and report the same annually to the governor, and, as far as practicable, to give information and advice respecting the best methods of preserving woodlands and starting new plantations. He shall also, as far as practicable, procure statistics of the amount of timber cut during each year, the purposes for which it is used, and the amount of timber land thus cleared as compared with the amount of land newly brought under timber cultivation, and shall in general adopt all such measures as, in his judgment, may be desirable and effective for the preservation and increase of the timber lands of this State, and shall have direct charge and control of the management of all forest lands belonging to the Commonwealth, subject to the provision of law relative thereto. * * *

SEC. 4. There shall be one deputy secretary, who shall be appointed by the governor for the term of four years, at a salary of three thousand dollars a year, who shall also be director of farmers' institutes. The other officers of the department shall be appointed by the governor for the term of four years, and shall be an economic zoologist, a commissioner of forestry, a dairy and food commissioner, who shall have practical experience in the manufacture of dairy products, and a State veterinarian, who shall be a graduate of some reputable veterinary college, who shall receive an annual salary of twenty-five hundred dollars each. * * * The governor is hereby authorized to appoint one chief clerk of the department, at an annual salary of sixteen hundred dollars, a stenographer, at a salary of eight hundred dollars a year, and one messenger, at a salary of six hundred dollars a year, and the dairy and food commissioner, the commissioner of forestry, and the economic zoologist shall each have a clerk, who shall be appointed by the governor and who shall serve under the direction of the respective commissioners aforesaid and receive a salary of fifteen hundred dollars a year each.

* * * * * * *

SEC. 6. That the secretary may, at his discretion, employ experts for special examinations or investigations, the expenses of which shall be paid by the State treasurer in the same manner as like expenses are provided by law, but not more than five thousand dollars shall be so expended in any one year. In this annual report to the governor he may include so much of the reports of other organizations as he shall deem proper, which shall take the place of the present agricultural reports and of which thirty-one thousand six hundred copies shall be published and distributed as follows: To the senate, nine thousand copies; to the house of representatives, twenty thousand

copies; to the secretary of agriculture, two thousand copies; to the State librarian, for distribution among public libraries and for reserve work, five hundred copies; and to the State agricultural experiment station, one hundred copies.

SEC. 7. That the secretary of agriculture shall have an office at the State capitol, and it is hereby made the duty of the commissioners of public buildings and grounds to provide the necessary rooms, furniture, and apparatus for the use of the department.

SEC. 8. That all acts or parts of acts inconsistent herewith be, and the same are hereby, repealed.

The legislature of 1897, in addition to passing—

An act making constables of townships ex officio fire wardens for the extinction of forest fires, and for reporting to the court of quarter sessions violations of the laws for the protection of forests from fire, prescribing the duties of such fire wardens and their punishment for failure to perform the same, and empowering them to require, under penalty, the assistance of other persons in the extinction of such fires;

and

An act to amend the first section of an act entitled "An act to protect timber lands from fire," approved the second day of June, anno Domini one thousand eight hundred and seventy, providing for a penalty in case of the failure of county commissioners to comply with the terms of said act, after demand made upon them by the commissioner of forestry, and providing for the Commonwealth bearing part of the expenses incurred under said act;

also,

An act to authorize constables and other peace officers, without first procuring a warrant, to arrest persons reasonably suspected by them of offending against the laws protecting timber lands—

enacted the following laws, thus firmly establishing a forest policy for the State.

AN ACT for the preservation of forests and partially relieving forest lands from taxation.

Be it enacted, etc.:

SECTION 1. That in consideration of the public benefit to be derived from the retention of forest or timber trees, the owner or owners of land in this Commonwealth having on it forest or timber trees of not less than fifty trees to the acre, and each of said trees to measure at least eight inches in diameter at a height of six feet above the surface of the ground, with no portion of the said land absolutely cleared of the said trees, shall, on making due proof thereof, be entitled to receive annually from the commissioners of their respective counties during the period that the said trees are maintained in sound condition upon the said land a sum equal to eighty per centum of all taxes annually assessed and paid upon the said land, or so much of the said eighty per centum as shall not exceed the sum of forty-five cents per acre: *Provided, however,* That no one property owner shall be entitled to receive said sum on more than fifty acres.

SEC. 2. All acts or parts of acts inconsistent herewith are hereby repealed.

AN ACT authorizing the purchase by the Commonwealth of unseated lands for the nonpayment of taxes for the purpose of creating a State forest reservation.

Be it enacted, etc.:

SECTION 1. That from and after the first day of January, anno Domini one thousand eight hundred and ninety-eight, whenever any unseated lands within this Commonwealth shall, under existing laws, become liable to sale by the respective county treasurers or the county commissioners for non-payment of taxes, it shall be the duty of such treasurers and commissioners to publish a notice once a week for six successive weeks in at least two newspapers of general circulation within the county in which the lands lie, and if two newspapers be not published in said county, then in one newspaper in or nearest to the same, which notice shall contain the names of the owners when known, the warrant numbers, names of warrantees when known, the number of acres contained in each tract, the township in which the same is located, and the sums due upon each tract for taxes, and, further, to mail to the secretary of agriculture and the commissioner of forestry each ten copies of such printed advertisement immediately upon the publication thereof.

SEC. 2. It shall be the duty of the commissioner of forestry to inquire into and examine the location and character of the lands so advertised, and if in his judgment the same are so located and are of such a character as to make them desirable to the Commonwealth for the purpose of creating and maintaining a forestry reservation, he shall have power, at his discretion, to purchase any such lands for and in behalf of the Commonwealth at such tax sales, subject to the right of redemption under existing laws: *Provided, however,* That the bid made and the price paid for said lands shall in no case exceed the amount of taxes for the nonpayment of which the same are being sold, and the costs. For all purchases so made in behalf of the Commonwealth the auditor-general shall draw his warrant upon the State treasurer to the order of the county treasurer, upon certificate filed by the commissioner of forestry with the said auditor-general.

SEC. 3. In the event of redemption of said lands, the redemption money paid shall be remitted to the State treasurer by the county treasurer, with a statement describing the tract of land so redeemed.

SEC. 4. The title to all lands so purchased, and not redeemed after the expiration of the time limited for redemption, shall be taken as vested in the Commonwealth to the same extent and with like effect as though such purchase had been made by an individual at such sale, and the county treasurer shall certify to the secretary of agriculture lists of all lands purchased in behalf of the Commonwealth and not redeemed within the time limited

for such redemption, with a description of each tract as required by section one of this act, and thereafter such lands shall not be subject to further taxation while the same are owned by the Commonwealth. It shall be the duty of the secretary of agriculture to keep a record in a book, to be especially provided for that purpose, of all the lands so acquired by the Commonwealth, with full description of each tract, the character of the same, the date of purchase, the price paid, when the title became absolute, or, if redeemed, the date of redemption.

SEC. 5. The lands so acquired by the Commonwealth shall be under the control and management of the department of agriculture, but assigned to the care of the division of forestry, and shall become part of a forestry reservation system having in view the preservation of the water supply at the sources of the rivers of the State, and for the protection of the people of the Commonwealth and their property from destructive floods.

SEC. 6. All acts and parts of acts inconsistent herewith are hereby repealed.

Approved the 30th day of March, A. D. 1897.

AN ACT to secure State forestry reservations, and providing for the expenses thereof.

Be it enacted, etc.:

SECTION 1. That a commission, to be composed of the commissioner of forestry, the chairman of the State board of health, the deputy secretary of internal affairs, and two other persons, one of whom shall be a lawyer or conveyancer of at least ten years' professional experience, and the other one a practical surveyor, to be appointed by the governor, be hereby created.

SEC. 2. The said commission shall, after examination, locate and report to the governor, or to the legislature if it be in session, the following forestry reservations:

(1) One of not less than forty thousand acres upon waters which drain mainly into the Delaware River.

(2) One of not less than forty thousand acres upon waters which drain mainly into the Susquehanna River

(3) One of not less than forty thousand acres upon waters which drain mainly into the Ohio River.

Provided, That each of these reservations shall be in one continuous area so far as the same is practicable.

SEC. 3. That the lands selected shall be of a character better suited to the growth of trees than to mining or agriculture, and that at least fifty per centum of the area of each reservation shall have an average altitude of not less than six hundred feet above the level of the sea.

SEC. 4. That the said commission shall have full power to take by right of eminent domain and condemn the lands it has selected for the purposes aforesaid as State reservations for the use and behoof of the Commonwealth, and wherever it shall be necessary to have a recourse to a jury to assess the damages for any property to be taken as aforesaid the said jury shall consist of such number and shall proceed, and their award shall be reviewed and enforced, in the same manner as now provided by law for the taking of land for the opening of roads in the respective counties in which said property is situated. And all the lands acquired by the State for public reservations by the action of said commission shall be paid for by the State treasurer, upon a warrant drawn by the auditor-general of the Commonwealth, after approval by the governor.

SEC. 5. The commissioners appointed under this act shall serve without compensation, except so far as the officials designated hereby are compensated by the continuance of their salaries as such officials while serving as commissioners; but the necessary expenses of travel and all other necessary expenses incurred under the provisions of this act shall be paid by the State treasurer, on the warrant of the auditor-general, after due certification.

SEC. 6. *Provided,* That nothing herein contained shall authorize the taking, for the purpose of this act, of any land held by any corporation created for the purpose of the preservation of forests.

Approved the 25th day of May, A. D. 1897.

The forest reservations provided by this law have been in part and will soon be all located. It is already being realized that their area is too small and that increase at once is indicated.

In North Carolina a similar provision to that in New Jersey has existed since 1891 in the laws appropriating for the State geological survey, requiring of the same reports on the forest resources. Three bulletins (Nos. 5, 6, and 7) have been published, one on the "Forest, forest lands, and forest products of eastern North Carolina," another on "Forest fires: Their destructive work, causes and prevention," and the third giving a comprehensive survey of the "Timber trees and forests of North Carolina."

In the West Virginia legislature a well-considered bill was introduced last year providing for a forest commission and State forest reserves. The State geological survey has functions similar to that of North Carolina.

In Ohio a forestry bureau was instituted in 1885, its functions being of an educational and advisory nature. It published four or five annual reports containing information on a variety of subjects, but for a number of years these reports, and probably the bureau, have been discontinued.

Michigan had a commission of inquiry, created in June, 1887, by constituting the State board of agriculture a forestry commission for the purpose of formulating the needed legislation. The report of this commission, published in 1888, remained without any active measure as a consequence.

The latest legislation for a commission of inquiry was enacted in Wisconsin in 1897:

AN ACT to provide for a committee to draw up a plan to protect and utilize the forest resources of the State of Wisconsin.

The people of the State of Wisconsin, represented in senate and assembly, do enact as follows:

SECTION. 1. The governor is hereby authorized to appoint a commission consisting of three members who shall devise and draw up a plan for the organization of a forestry department, which shall have the management of such State lands as may be suitable for timber culture and forestry. The said commissioners shall embody in their plan provisions for the classification of the lands now owned by the State and the reservation to the State of all lands which are better fitted for the growing of timber than for agricultural purposes; the purchase of similar lands which may have been abandoned by their owners, or may have been struck off to counties for unpaid taxes; the management of the forests existing on such lands according to the principles of scientific forestry; the replanting of forests on such lands, as far as they have been denuded of their timber; and such other provisions as may be deemed advisable. They shall aim at devising the best means by which the forest resources of the State can be utilized for the people and preserved for future generations without retarding the development of the agricultural, manufacturing, and mining industries; shall have regard to the influence which the maintaining of forests has upon the climate and water supply of the State; and shall draw up a plan by which the forestry department may be from the first self-supporting and in time become a source of revenue to the State. The report of said commissioners shall be submitted to the legislature of the State at its next regular session, within the first ten days after the beginning thereof, in the form of a bill or bills.

SEC. 2. Said bill or bills may be accompanied by a report explaining the provisions of such bill or bills and giving the reasons for any of the provisions contained therein. The said bill or bills, together with such report, shall be printed by the State printer at the expense of the State in not more than five hundred copies, and shall be distributed to such persons as the governor may direct.

SEC. 3. The said commissioners shall receive no compensation for their services, but shall be entitled to their actual and necessary expenses, including clerk hire, which expenses and clerk hire shall not, in the aggregate, exceed two hundred and fifty dollars, to be paid by the State treasurer upon warrants drawn by the secretary of state, upon verified statements made by the chairman of such commission. The superintendent of public property shall furnish such commission with the suitable and necessary stationery for the performance of such work.

SEC. 4. There is hereby appropriated, out of any money in the treasury not otherwise appropriated, a sufficient sum to carry out the provisions of this bill.

SEC. 5. This act shall take effect and be in force from and after its passage and publication.

Approved April 14, 1897.

The commission appointed by the governor sought the cooperation of the Division of Forestry of the Department of Agriculture, whose experts, in cooperation with the State geological survey, made a comprehensive forest survey of the forested counties of the State, upon the basis of which the commission is framing its propositions.

The State also has an effective forest-fire law, which is in charge of a special commissioner, as will be shown later.

In Minnesota, as a consequence of the terrible warning by the fires of 1894, on April 18, 1895, the legislature passed "an act to provide for the preservation of forests and for the prevention and suppression of forest fires," under which the State auditor was made ex officio forest commissioner, with a chief fire warden as executive officer in charge of the organized service to combat forest fires. Beyond these duties the latter officer is only required to add to his report "suggestions relative to the preservation of the forests of the State and to the prevention and extinguishment of forest and prairie fire." Three annual reports have so far appeared and show the wisdom of the legislation.

An effort was made during the legislative session of 1897 to secure the enactment of the following bill, which passed the house but failed to reach a vote in the senate. The bill is included here, notwithstanding its failure to become a law, because it embraces a novel and interesting method of securing to the State the benefits of a forest reservation.

AN ACT to encourage the growing and preservation of forests, and to create forest boards and forest reserve areas.

(Sections 1 to 8 provide for the acquirement of forest reserve areas, the appointment of a forestry board of nine members, who shall serve without pay other than the reimbursement of actual expenses incurred, and who shall have a secretary, and elect a president and vice-president. The State treasurer is made treasurer of the board, and county commissioners and town supervisors are made county and town forestry boards. The duties of the boards are defined, and the remainder of the bill, embracing its unique features, is as follows:)

SEC. 9. Any person or corporation being the owner in fee simple of any cutover or denuded, or partially cutover or partially denuded, natural forest lands, which will not probably be utilized for many years for agricultural purposes, or any bare or waste, or partially bare or waste, rough prairie lands, or any very sandy, very rough, or

very rocky lands in this State, or any lands deemed absolutely necessary for the preservation of water courses (all to be determined by said State forestry board) may deed the same to the State of Minnesota for forestry purposes; all lands so deeded to the State for forestry purposes by any person or corporation are hereby forever dedicated for forestry purposes.

Before such deed shall be made and delivered a proposition in writing shall be made by such owner or owners to said State forestry board to so deed the same for forestry purposes, under the terms of this act and amendments thereof, made prior to such offer, and the question of the acceptance thereof shall be referred to the town or county forestry board where the land is situated (or both such town and county forestry boards) for its advice on the question of accepting the same; and said State forestry board, or its executive committee, may hear the person offering so to deed, or his or her representative, and also may hear such town or county forestry board or its representative, both sides in person, or by written reasons submitted, why such deed should or should not be received, and the decision of the State forestry board to receive or reject such offer and deed shall be final. Such deed may be made by quitclaim, where by the advice of the attorney-general, or by the advice of its attorney, if said board have one, said lands are clear of liens except for taxes and tax sales still owned by the State.

The board may appoint an executive committee annually, on which it may confer authority to perform any executive act, and to exercise its judgment in minor details which can not conveniently be acted upon by the board.

SEC. 10. At least once in every five (5) years, and as much oftener as the State forestry board may decide, the accumulated income from each tract of land so deeded by persons or corporations for State forestry purposes shall be divided by the State forestry board and disposed of as follows, to wit:

1st. One-third ($\frac{1}{3}$) shall belong to the State, to reimburse the State for the care and protection of the forests thereon, and for the nonpayment of taxes thereon to the State, county, and town, which third ($\frac{1}{3}$) shall be divided between the State, county, and town where the land is situated as follows, to wit: One-half ($\frac{1}{2}$) to the State, one-fourth ($\frac{1}{4}$) to the county, and one-fourth ($\frac{1}{4}$) to the town.

2d. Two-thirds ($\frac{2}{3}$) shall be paid to such public educational institution or system in the State as the grantor may designate in the deed of conveyance, or in a separate instrument executed as deeds of land are required to be executed and recorded in the office of the register of deeds of the county where the land is situated, or by will. But in case the grantor fail to so designate such institution or system, or if for any reason such institution or system fails to exist, then the same shall paid to the proper officer or officers or boards for the benefit of the public school system of the State and the University of Minnesota, the public school system to have three-fourths ($\frac{3}{4}$) thereof, and the said university to have one-fourth ($\frac{1}{4}$) thereof.

SEC. 11. The State, by and through said State forestry board, shall have full power and authority to lease for revenue, or for protection from fire, trespassers, or otherwise, low meadow tracts, or other tracts for pasture, when the same will not interfere with the growth of forest trees, and to sell dead and down timber and mature timber, and to deed said tracts or parcels or parts of the same, where the growth of towns, the building of railroads, water powers, or other public improvements may demand alienation by the State, and said State forestry board may cause to be cut and sold, or sold with the right to cut and haul away, forests or trees when said board may determine that the State's and the beneficiaries' interests will be subserved by so doing, but all proceeds of such sales or leases shall be divided as is the income therefrom as above provided.

SEC. 12. This act shall take effect and be in force from and after its passage.

In North Dakota the office of commissioner of irrigation and forestry was created in 1890, seemingly mainly for educational purposes. In Kansas for some time the educational campaign for timber planting of the State horticultural society was supplemented by the State in the establishment of two experimental tree stations, under a superintendent, from which plant material is distributed to intending planters.

The State of Colorado was the first to recognize in her constitution the existence of a duty on the part of the government with regard to her forestry interests.

Article XVIII of the constitution, adopted in convention March 14, 1876, contains the following clauses:

SEC. 6. The general assembly shall enact laws in order to prevent the destruction of and to keep in good preservation the forests upon the lands of the State or upon lands of the public domain, the control of which shall be conferred by Congress upon the State.

SEC. 7. The general assembly may provide that the increase in the value of private lands caused by the planting of hedges, orchards, and forests thereon shall not, for a limited time, to be fixed by law, be taken into account in assessing such lands for taxation.

The constitutional convention also presented a memorial to Congress asking for the transfer of the public-timber lands in the then Territory to the care and custody of the State, which remained, however, without attention.

The intentions of the constitution to take care of the forestry interests of the State were, however, not carried into effect until 1885, when a law was passed creating the office of a forest commissioner and constituting the county commissioners and road overseers throughout the State, forest officers in their respective localities, to act as a police force in preventing depredation

and fire, and to encourage and promote forest culture. But the provisions to carry out this laudable work were from the start insufficient, and the office of forest commissioner finally remaining without a salary became vacant, the law ineffective. A new departure, however, was made in 1897. In that year a department of forestry, game, and fish was created. The salaried officers provided are a commissioner and three wardens, and the commissioner may appoint deputy wardens without pay. Section 9 of the law provides that—

> Said commissioner shall, as much as possible, promote the growth and extension of the forest areas of the State, and encourage the planting of trees and the preservation of the sources of water supply, but nothing in this act contained shall authorize the commissioner to interfere with the use of timber for domestic, mining, or agricultural purposes, in accordance with existing laws. He shall have the care of all woodlands and forests which may at any time be controlled by the State, and shall cause all such lands to be located and recorded in a book to be kept for the purpose.

Section 10 prohibits the appointment to any office created by this act of any person directly or indirectly engaged in the manufacture of lumber, railroad ties, telegraph poles or any business requiring a large use of wood. The law makes it a misdemeanor to cause fires to be set without a guard, or to cut coniferous timber from public or State lands for shipment outside the State. The remainder of the law provides for the protection of fish and game.

California began its course for the establishment of a forest policy in the most promising manner in 1885, March 3, by creating a State board of forestry. At first it was mainly a commission of inquiry with educational functions; police powers were conferred upon it in 1887 "for the purpose of making arrests for any violation of any law applying to forest and brush lands within the State, or prohibiting the destruction thereof," with an appropriation of $30,000 for the two years following, but by 1891 political complications and perversion of the moneys appropriated undid the good work of the first board, and the office, as well as the functions, were abolished. Besides three valuable reports on the forest conditions and forest trees of the State, the board left as an inheritance two experiment stations, where exotic trees are being tested, now under charge of the University of California.

FOREST-FIRE LEGISLATION.

Besides this legislation regarding forest commissions, by which the interest and duty of the State is recognized with regard to forest conditions, laws recognizing the duty and necessity of protecting forest property more efficiently against fire have been enacted in several States since 1885, when, in New York in connection with the establishment of the forest commission, the first comprehensive forest-fire law, drafted by the writer, was enacted. Laws against willful and malicious firing existed then on the statute books of nearly every State, but they were ineffective for lack of responsibility for their execution. The New York law for the first time recognized the need of officers responsible for the execution of the law and of the organization of an army of firewardens throughout the State.

The States of Maine, New Hampshire, Pennsylvania, Wisconsin, and Minnesota followed, with some modifications, this example of New York.

The principles most needful to keep in view when formulating legislation for protection against forest fires are—

(1) No legislation is effective unless well-organized machinery for its enforcement is provided. The damage done by forest fires being in many cases far-reaching beyond the immediate private personal loss, the State must be prominently represented in such organization.

(2) Responsibility for the execution of the law must be clearly defined and ultimately rest upon one person, and every facility for ready prosecution of offenders must be at the command of the responsible officer.

(3) None but paid officials can be expected to do efficient service, and financial responsibility in all directions must be recognized as alone productive of care in the performance of duties as well as in the obedience to regulations. In the case of corporations the officer most directly responsible for any damage must be amenable to law in addition to the corporation itself.

(4) Recognition of common interest in the protection of property can also be established only by the creation of financial liability on the part of the community and all its members.

The following is the draft of an ideal comprehensive bill which embodies the principal features of the desired legislation and has served as a basis for the existing laws:

AN ACT for the protection of forest property.

FOREST COMMISSIONER.

Section 1 creates a forest commissioner, whose office may be either an enlargement of some existing office or, much better, a separate one, with adequate compensation in either case, to be appointed by and reporting directly to the governor.

Section 2 prescribes the duties of the forest commissioner, namely, to organize, supervise, and be responsible, under the provisions of this act, for the protection of forest property in the State against fire. In addition he is to collect statistics and other information regarding the forest areas in the State, and the commerce of wood and allied interests, especially such information as will explain the distribution, condition, value, and ownership of the woodland; this information and the results of the operation of this act, together with suggestions for further legislative action, to be embodied in annual reports.

Section 3 provides for the giving of a bond by the forest commissioner for the faithful performance of his duties, and fixes fines for such neglect in performing the duties of the office as may be proven, and explains the manner of imposing and collecting such fines.

ORGANIZATION OF FIRE SERVICE.

Section 4 constitutes the selectmen of towns, or the sheriffs, deputies, constables, supervisors, or similar officers as firewardens. If preferred, special fire commissioners may be appointed by the forest commissioner, with the advice of county commissioners, or both methods of providing firewardens may be employed together. The towns are to be divided into fire districts, the number and boundaries to be governed by the exigencies in each case, and each district to be under the charge and oversight of one district firewarden. One of these should be designated as town firewarden, to take command in case of large conflagrations. The town firewarden and at least 50 per cent of the district firewardens should be property owners in the county, unless a sufficient number of such can not be found or residents refuse to serve. A description of each district and the name of its firewarden are to be recorded with the forest commissioner and the town clerk or similar officer.

Section 5 provides for employment of special fire patrols in unorganized places in any county and during the dangerous season, especially in lumbering districts, and for co-operation of forest owners. Wherever unorganized places exist in a county or so far distant from settlements as to make discovery of fires and speedy arrival of regular firewardens impossible, or wherever forest owners whose property is specially endangered require, the forest commissioner may annually appoint special fire patrols, to be paid at daily rates, the owner paying one-half the expense and the State the other half; such patrols to be under the regulations of this law and to report to the nearest firewardens. The manner of appointment and the matter of compensation and duties are to be formulated by the forest commissioner.

Section 6 defines the power and duties of firewardens: To take measures necessary for the control and extinction of fires; to post notices of regulations provided in this law and furnished by the forest commissioner; to ascertain the cause of fires and prepare evidence in case of suits; to report each fire at once to the forest commissioner on blanks furnished, giving area burned over, damage, owner, probable origin, measures adopted, and cost of extinguishing; to have authority to call upon any persons in their district for assistance, such persons to receive compensation as determined by the selectmen or county commissioners at the rate of not to exceed 15 cents per hour and to be paid by the town or county upon certification by the forest commissioner.

Persons refusing, when not excused, to assist or to comply with orders, shall forfeit the sum of $10, the same to be recovered in an action for debt in the name and to the use of the town or county, or for the fire-protection fund.

Firewardens shall be paid $10 a year as a retainer besides day's wages at the same rates as sheriffs or similar officers for as many days as they are actually on duty, and shall be responsible for prompt extinction of fires and be amenable to law for neglect of duty. The district firewarden shall call on the town firewarden in case of inability to control fires, and the town firewarden shall have sheriff's power to enlist assistance, as is provided in case of a mob.

FIRE-INDEMNITY FUND.

Section 7 provides for the creation of a fire-indemnity fund, each county to pay into the State treasury $1 for each acre burnt over each year, the special fund so constituted to be applied in the maintenance of the system provided by this act and for the payment of damages to those whose forest property has been burned without neglect on their part or on that of their agents.

The burned areas shall be ascertained by the county surveyor and shall be checked from the reports of firewardens by the forest commissioner. All fines collected under the provisions of this law shall also accrue to the fire fund.

JURISDICTION AND LEGAL REMEDIES.

Section 8 establishes jurisdiction and legal proceedings in each case of prosecution of incendiaries and adjustment of damages, and imposes upon every district judge the duty in charging the grand juries of his district to call special attention to the penal provisions of this act and of any similar acts providing for offenses against forest property.

Section 9 charges the forest commissioner to issue and publish, by posters and otherwise, reasonable regulations regarding the use of fires; such regulations to contain special consideration of campers, hunters, lumbermen, settlers, colliers, turpentine men, railroads, etc., and to be approved by the governor.

Section 10 makes it a misdemeanor to disobey the posted regulations of the forest commissioner, or to destroy posters, or to originate fires by neglect of the same; provides that the prosecution shall be prepared by the forest commissioner, and imposes fines and imprisonment in addition to damages. Fines should be double the actual damages, one-half to go to the fire fund, one-half to the damaged person.

Section 11 makes it a criminal act, subject to indictment, to willfully set fires, and imposes fine and imprisonment.

Section 12 provides that any person whose forest property is damaged by fire not originated by his own neglect, and who is able to prove neglect on the part of the firewarden, may call on the forest commissioner for award of damage, whereupon the forest commissioner, in conjunction with the county authorities, shall investigate the case and refer his findings to the judicial officer of the district, who shall charge the grand jury to indict any offender against this act and adjudge any neglectful firewarden or other officer or any person refusing to act upon orders of the firewarden.

Any neglect on the part of the forest commissioner to investigate and find in each case within one year from the appeal of the owner shall be followed by dismissal unless reasonable cause for failure be shown.

LIABILITY OF RAILROADS.

Section 13 charges railroad companies to keep their right of way free from inflammable material by burning, under proper care, before certain dates to be established by the forest commissioner. Failure to do so upon notification by the commissioner shall be followed by the arrest of the superintendent of the section, who shall be liable prima facie to procedure under section 10.

Section 14 provides for the use of spark arresters, failure to comply with this provision to be followed by arrest of the superintendent or other officer in charge of the motive power and by procedure under section 10.

Section 15 provides that fires originating from the tracks of a railroad company shall be prima facie evidence of neglect on the part of the company, and the engineer and firemen shall be liable to arrest and procedure under section 10.

Section 16 provides that in all cases where a fire originates through neglect of a railroad company or its agents, both the company and its officers shall be liable for damages under the provisions of section 12.

Section 17 establishes special liabilities for damage by fires in case of railroads under construction.

FIRE INSURANCE AND STOCK LAWS.

Section 18 provides for the incorporation of forest fire insurance companies. In States where cattle are allowed to roam, provisions to stop this practice should be enacted.

FURTHER DUTIES OF FOREST COMMISSIONERS.

Section 19 defines minor duties of forest commissioners, namely, to co-operate with superintendents of schools and other educational institutions in awakening an interest in behalf of forestry and rational forest use.

Section 20 provides for salary and other expenses of the office of forest commissioner, which should be liberal in proportion to the responsibility of the office.

Section 21 repeals all acts and parts of acts inconsistent with provisions of this act.

How near to this ideal we come in practice may appear from the legislation enacted for Minnesota in 1895, which is still only partially effective on account of deficient appropriations and limited functions of the commissioner or chief firewarden.

AN ACT to provide for the preservation of forests of this State and for the prevention and suppression of forest and prairie fires.

Be it enacted by the legislature of the State of Minnesota:

SECTION 1. The State auditor shall be forest commissioner of this State, and his orders shall be supreme in all matters relating to the preservation of the forests of this State and to the prevention and suppression of forest and prairie fires as hereinafter provided. The supervisors of towns, mayors of cities, and presidents of village councils are hereby constituted firewardens of their respective towns, cities, and villages in the State, and the chief firewarden may appoint as firewardens such other persons as he may deem necessary, living in or near to unorganized territory in this State, whose districts, to be known as fire districts, he may determine.

SEC. 2. The aforesaid forest commissioner shall appoint a competent deputy to be known as chief firewarden, who, from personal experience, is familiar with the conditions of the forest and methods by which fires may be controlled. Said chief firewarden shall receive a salary of twelve hundred ($1,200) dollars per year, and shall hold his office during the pleasure of the forest commissioner. He shall represent the authority of the forest commissioner, and it shall be his duty to enforce the provisions of this act throughout the State.

SEC. 3. The chief firewarden shall have general charge of the firewarden force of the State, and shall have authority to mass such firewarden force as may be available at any special point to suppress fires. In case the firewarden force of any locality is deemed by said chief firewarden inadequate to prevent or suppress forest or prairie

fires, he may appoint, temporarily, needed firewardens, whose duties and authority shall be the same as herein given to town supervisors acting as firewardens. He shall properly divide into fire districts all unorganized territory in this State and appoint competent firewardens therein; he shall co-operate with any police or military force of the United States Government which may be detailed to guard the national domain from fire; he shall investigate the extent of the forests in the State, together with the amounts and varieties of the wood and timber growing therein, the damages done to them from time to time by forest fires and the causes of such fires, the method used, if any, to promote the regrowth of timber, and any other important facts relating to forest interests which may be required by the forest commissioner. The information so gathered, with his suggestions relative thereto, shall be included in a report to be made by him annually to the forest commissioner.

SEC. 4. The forest commissioner shall provide and officially sign an abstract of the penal laws of this act, with such rules and regulations in accord therewith as he may deem necessary, and on or before the first day of April of each year he shall forward as many copies as he considers needful to the chairman of each town board of supervisors and presidents of villages, to the forest firewardens that he has appointed, and to all railroad companies and to the chairman of each board of county commissioners in this State, and it shall be the duty of said firewardens to post up such abstract as warning placards in conspicuous places in their respective districts, and it shall be the duty of the county commissioners of each county to cause the said abstract to be published in at least three issues of the official papers in their respective counties during the fire-dangerous season of each year, which shall be reckoned from the 15th of April to the 1st of November.

SEC. 5. During a dry and dangerous season, when forest and prairie fires are prevailing or are liable to break out, the chief firewarden shall use such means under his command as he may deem necessary to prevent or suppress such fires, and his expenses shall be paid by the State, which expenditures in one year shall not exceed five thousand dollars, to be paid for out of the general revenue fund, upon the order of the forest commissioner.

SEC. 6. It shall be the duty of each fire warden to take precautions to prevent the setting of forest or prairie fires, and when his district is suffering or threatened with fire, to go to the place of danger to control such fires, and each forest firewarden shall have authority to call to his assistance in emergencies any able-bodied male person over eighteen years of age, and if such person refuses, without reasonable justification or excuse, to assist, or if any firewarden refuses or neglects to perform the duties assigned him in this act, such officer or person shall be deemed guilty of a misdemeanor, and shall upon conviction thereof be punished by a fine of not more than one hundred ($100) dollars, or imprisonment in the county jail not to exceed three (3) months.

SEC. 7. The chief firewarden and the several firewardens created by this act shall have authority to enforce the provisions of this act, and it shall be their duty to co-operate with the firewarden of any adjoining district, and in the absence of such firewardens to direct the work of control and extinguishment of forest or prairie fires in such district, and to arrest, without warrant, every person violating any provisions of this act, and to forthwith take the offender before a magistrate and make complaint against such person. The chairmen of boards of township supervisors, presidents of villages, and firewardens appointed by the chief firewarden shall inquire into the cause of each forest or prairie fire within their districts and shall report the same to the chief firewarden and the methods used to control or extinguish such fires and the amount of property destroyed and the number of lives lost, if any, and report such other facts in regard to said fires as said chief firewarden may require. During the more dangerous season of the year the chief firewarden may require frequent reports from the chairmen of township boards, or in unorganized towns from firewardens appointed by the said chief firewarden, as to condition of forest and prairie fires and as to what is being done to control the same.

SEC. 8. Each firewarden shall receive for his actual services rendered under this act two ($2) dollars per day, two-thirds of which shall be paid by the county where such service is performed and one-third by the State; and any employee engaged in like service shall receive at the rate of one and fifty one-hundredths ($1.50) dollars per day, and said expense shall also be paid, two-thirds by the county where such service is rendered and one-third by the State, as hereinafter provided; but no payment shall be made to any claimant under this act until he shall have presented an itemized account and made oath or affirmation that said account is just and correct, which account shall be approved by the board of township supervisors and shall be audited by the county commissioners, when satisfied of the justice of the claim, and left on file with the county auditor; in case of unorganized townships the board of county commissioners alone shall approve and audit such accounts. The county auditor shall thereupon issue to each claimant his warrant upon the county treasurer for the entire sum to which such claimant is entitled, and the treasurer shall pay the same. Such county auditor shall transmit the original oath and copy of the warrant to the State auditor, who shall audit such claim, and one-third thereof shall be paid out of the State treasury from the general revenue fund by warrant issued by the State auditor upon the State treasury in favor of the county thereof paying the same, and forward the same to the auditor of said county: *Provided*, That no firewarden shall be paid in any one year for more than ten (10) days' service in extinguishing and preventing forest or prairie fires, nor for more than five (5) days' service in each year in posting notices and making the reports required by this act, nor in the aggregate for more than fifteen (15) days' service, of whatever character, in any one year; nor shall any one person employed by firewardens to assist in extinguishing or preventing forest or prairie fires be paid for more than five (5) days of such service in any one year. No county shall expend more than five hundred ($500) dollars of public money in any one year under this act.

SEC. 9. Any person who willfully, negligently, or carelessly sets on fire, or causes to be set on fire, any woods, prairies, or other combustible material, whether or not on his own lands, by means whereof the property of another is injured or endangered, or any person who willfully, negligently, or carelessly suffers any fire set by himself to damage the property of another, is guilty of a misdemeanor and shall be punished by a fine not exceeding one hundred ($100) dollars, or by imprisonment in the county jail not exceeding three months. Any person who maliciously

sets on fire, or causes to be set on fire, any woods, prairies, or other combustible material whereby the property of another is destroyed and life is sacrificed shall be punished with a fine of not over five hundred ($500) dollars, or be imprisoned in the State prison for a term of not over ten (10) years, or both such fine and imprisonment.

SEC. 10. Any person who shall kindle a fire on or dangerously near to forest or prairie land and leave it unquenched, or shall be a party thereto, and every person who shall use other than incombustible wads for firearms, or who shall carry a naked torch, firebrand or other exposed light in or dangerously near to forest land, causing risk of accidental fire, shall be punished by a fine not exceeding one hundred ($100) dollars, or imprisonment in the county jail not exceeding three (3) months.

SEC. 11. Every person who shall willfully or heedlessly deface, destroy, or remove any warning placard posted under the requirements of this act shall be liable to a fine not exceeding one hundred ($100) dollars for each such offense, or imprisonment in the county jail not exceeding three (3) months.

SEC. 12. It shall be the duty of all railroad companies operating any railroad within this State to use efficient spark arresters on all their engines and to keep their right of way to the width of fifty (50) feet on each side of the center of the main track cleared of all combustible materials and safely dispose of the same within said limits of their right of way between the 15th day of April and the 1st day of December. No railroad company shall permit its employees to leave a deposit of fire or live coals, or hot ashes, in the immediate vicinity of woodland, or lands liable to be overrun by fires, and where engineers, conductors, or train men discover that fences or other materials along the right of way or woodland adjacent to the railroad are burning, or in danger from fire, they shall report the same promptly at the next telegraph station that they may pass. In seasons of drought railroad companies shall give particular instructions to their employees for the prevention and prompt extinguishment of fires, and they shall cause warning placards furnished by the forest commissioner to be posted at their stations in the vicinity of forest and prairie grass lands, and where a fire occurs along the line of their road they shall concentrate such help and adopt such measures as shall be available to effectively extinguish it. Any railroad company willfully violating the requirements of this act shall be deemed guilty of a misdemeanor and be punished by a fine not exceeding one hundred ($100) dollars for each such offense, and railroad employees willfully violating the requirements of this section shall be guilty of a misdemeanor and be punished by a fine of not less than five ($5) dollars nor more than fifty ($50) dollars. But this section shall not be construed to prohibit or prevent any railroad company from piling or keeping upon the right of way cross-ties or other material necessary in the operation or maintenance of such railroad.

SEC. 13. It shall be the duty of each and every owner of thrashing or other portable steam engines to have efficient spark arresters on their engines at all times when in use, and no person in charge of any thrashing engine shall deposit live coals or hot ashes from his engine in any place without putting them out or covering them with at least three inches of earth before leaving them. All persons violating the provisions of this section shall be deemed guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not less than five ($5) dollars nor more than fifty ($50) dollars.

SEC. 14. Nothing in this act shall be construed as affecting any right of action for damages.

SEC. 15. Woodland territory within the terms of this act shall be construed to mean bodies of forest and brush land.

SEC. 16. All moneys received as penalties for violating the provisions of this act shall be paid into the county treasury of the county wherein the offense occurred, to be known as the county fire fund, and used under the direction of the county board in defraying the expenses of enforcing the provisions of this act within such county.

SEC. 17. The forest commissioner shall annually, on or before the first day of December, make a written report to the governor of his doings in respect to the duties herein assigned him, together with an itemized account of the expenses incurred in carrying out the provisions of this act, which report shall include such statistics and facts as he has obtained from the chief fire warden and from the several fire wardens of the State and from other sources, together with his suggestions relative to the preservation of the forests of the State and to the prevention and extinguishment of forest and prairie fires.

SEC. 18. All acts and parts of acts inconsistent with this act are hereby repealed.

SEC. 19. This act shall take effect and be in force from and after its passage.

Approved April 18, 1895.

The Wisconsin law (chapter 266, Laws of 1895) is similar in general character to the Minnesota law, except that the chief clerk of the State land office and his deputy are made State forest warden and deputy forest warden, respectively, without additional salary. Towns are limited to $100 per year expenditure in extinguishing fires.

The Maine law (chapter 100, Public Laws of 1891) makes the State land agent the forest commissioner. The selectmen of towns are made fire wardens and their duties are to post copies of the law in conspicuous places and to superintend the work of extinguishing fires. They are empowered to call upon any person for assistance, and a refusal makes the party liable to $10 fine. The county commissioners in counties where there are unorganized places may appoint not to exceed ten fire wardens. No town shall expend for extinguishing fires more than 2 per cent of its valuation for purposes of taxation. Anyone who neglects to extinguish a camp fire is liable to a fine not exceeding $100 or imprisonment in the county jail one month, or both. Non-combustible wads must be used by hunters. Municipal officers (and county commissioners in unorganized

places) shall make strict inquiry into the causes of fires within wooded lands, and prosecute the offender without delay. Town selectmen shall, where a forest fire of more than one acre has occurred, report to the forest commissioner the extent of fire and the amount of loss, and the measures found efficient in subduing fire, for which purpose blanks shall be furnished by the forest commissioner.

Railroad companies are required to have their employees burn or cut and remove all grass, etc., from their right-of-way once a year; to use spark arresters on their locomotives; to refrain from depositing live coals, fire, or ashes on their track; and to report fires along right-of-way at the next stopping place that is a telegraph station. Railroad companies are held liable for all damage to forest growth by any person in their employ during road construction. During construction of such roads through woodland, abstracts of the laws relating to forest fires shall be posted along the roadway at distances of 200 feet. Anyone so employed who fails to extinguish a fire made by him is liable to a fine not exceeding $500 or imprisonment not exceeding sixty days, or both, and it is made the duty of all persons having charge of men in such railroad construction to see that the provisions of this act are complied with, any negligence subjecting them to the punishment above named. Violations of this act by railroads are punishable by a fine of $100 for each offense. The forest commissioner shall encourage an interest in forestry in the public schools, and shall prepare circulars of information giving advice for the care of woodlands. He shall have copies of this chapter and all other laws of the State relating to forest fires printed and freely distributed to the selectmen of all the towns of the State, who shall post them up in schoolhouses, sawmills, logging camps, and other places, and to forest owners, who may post them at their own expense. Anyone defacing or destroying such notices is liable to a fine of $5.

Reports of the commissioners all bear testimony to the beneficent effect of the legislation, especially in educating people to consider the value of forest property, although the execution of the laws is still difficult and unsatisfactory.

That it is not necessary to have forest fires, or that they can be at least reduced to insignificant dimensions, may be learned from the experiences of other nations, who exercise the first function of the State, namely, the more thorough protection of life and property of its citizens.

In a recent report we read that in 1896 "very considerable damage by fire" occurred in the Prussian State forests (some 6,000,000 acres), and then the reporter brings a table showing that altogether less than 2,500 acres were burnt over. One "extensive" fire is reported as destroying 1,000 acres of "hopeful" pine and spruce plantation 20 to 25 years old, the result of incendiarism.

In the following year (1897) the entire loss was not over 100 acres. During the ten years 1882 to 1891 there were 156 cases of fire reported: 96 from negligence, 53 from malice, 3 from lightning, and only 4 from locomotives; and seven years out of the ten are without any record of fire due to this last cause. And this on an area of 6,000,000 acres, of which more than half is on dry sandy soil stocked with pure pine forest, where the pine litter is never burned or removed, and with large bodies of sapling timber and young growth interspersed.

Comment is unnecessary as to the possibility of protecting forest property from fire.

The Indian forest administration, under circumstances not less difficult, nay, perhaps, more difficult than those prevailing in the United States, still more strongly refutes the assertion that forest fires may not be suppressed.

Not only have the people of all timbered parts of India practiced the firing of woods for many centuries, both for purposes of agriculture and pasture, but the natural conditions in most of the Indian forests are such as to discourage the most sanguine.

In most parts the forest is a mixed growth, of which a considerable portion is valueless and is left to die and litter the ground with dry and decaying timber, furnishing ready fuel. To this is added a mass of creeping and climbing vegetation, a dense undergrowth, largely composed of giant grasses and bamboos, covering the ground with standing or fallen canes, green and dry. It is a dangerous forest; and yet the forest department fights and prevents fires, and succeeds.

The number of fires has been diminished to an astonishing degree, the efficiency has grown with perfection of methods, and the expenses have been constantly reduced, and have never been over $10 per square mile in any year. And this in a country where heat and moisture stimulate a rank growth, where a clearing will be covered in one year with grass in which an elephant can hide, and where hot, dry winds make a most dangerous forest-fire combination every year.

There is no insuperable difficulty in stopping the fire nuisance in this country, provided the moral obligation is recognized, the will is there, and the necessary organization is provided.

FORESTRY EDUCATION.

The New York legislature of 1898 made provision for the establishment of a college of forestry in Cornell University, and provided for the purchase of a school forest of 30,000 acres to be used as an experimental demonstration area for illustrating the principles and practice of scientific forest management. The school was organized in April, 1898, with Dr. B. E. Fernow as director and dean.

Its first session opened in September, with the beginning of the collegiate year 1899. This is the first professional school of forestry established in America which offers in its courses the same full complement of studies to be found in European institutions of similar kind.

As indicating the scope of the subject and the requirements for a fully educated forester of highest degree, the following schedule of studies announced by the college is reproduced.

This step firmly establishes the forest policy of the State of New York, eventually to place its large forest property under the management of technically educated foresters issuing from this State college.

Schedule of the courses leading to the degree of Bachelor of the Science of Forestry (B. S. F.).

[Courses in parentheses are elective in whole or in part.]

	Designation of courses.	First term.	Second term.	Third term.
FRESHMAN YEAR.				
Mathematics	7	2	2	2
Do	10	(3)	(3)	(3)
Physics	2a	2	2	2
Do	2b	(5)	(5)	(5)
Chemistry	1	3	3	3
Invertebrate zoology	1	3		
Vertebrate zoology	2		3	
Entomology	3			3
Botany	1	3	3	
Do	2			3
Geology	10		3	
Do	23	2		
Forestry	1			2
SOPHOMORE YEAR.				
Chemistry	16	4	4	(4)
Entomology	2	2	2	2
Botany	9	3		
Do	5			(1)
Geology	1	3		
Do	21	3	3	3
Do	32		2	
Engineering	4		6	
Do	5			8
Political economy	34			3
Forestry	2	(3)	(3)	(3)

	Designation of courses.	First term.	Second term.	Third term.
JUNIOR YEAR.				
Chemistry	21b	2		
Botany	11	3	3	
Geology	20	3		
Do	22	(3)	(3)	(3)
Engineering	11		1	2
Political economy	51		3	3
Pisciculture and venery		3		
Forestry	3	3	3	3
Do	4			3
Do	6		3	
Do	7		3	3
SENIOR YEAR.				
Political economy	59	2	2	2
Law		2	2	2
Forestry	5	3	3	
Do	8	4		
Do	9			2
Do	10			2
Do	11		3	
Do	12		2	2
Seminary and thesis			2	2
Electives		3	3	3

The resources of the entire university, with its library, laboratories, museums, and collections, are practically at the disposal of the college by the action of the board of trustees, and hence, besides the required courses, any additional courses offered by the various departments which are thought to be of special value to forestry students may be elected by them whenever they have satisfied the requirements.

The courses in fundamental and supplementary branches, which are needful and required for the three or four year forestry courses and for graduation, are selected from those offered in the departments of the university.

The courses in forestry are briefly described as follows:

1. Synoptical course in forestry. Economic nature and political aspects. Designed especially for students of political economy, agriculture, engineering, and freshmen in the college of forestry, to acquaint the student in a brief manner with the several subjects comprising the field of forestry. Lectures only. Two hours, fall or spring.

2. One-year course in forestry, with special reference to silviculture. Designed especially for agriculturists and others who desire a brief study of the technicalities of woodcraft and silviculture. Lectures and demonstrations. Three hours, through the year.

3. Silviculture. Principles of arboriculture, application of dendrology to crop production, methods of

reproduction, improvement of the crop, nursery practice, and forest planting. Lectures, recitations, and field demonstrations. Three hours, through the year.

4. Forest protection. Methods of guarding against trespass, loss from fires, insects, and diseases; measures to prevent erosion, washing, and deterioration of soils. Lectures and recitations. Three hours, spring term.

5. Timber physics and wood technology. Technical properties of wood and its uses. The course is arranged to meet also the needs of students in civil engineering and architecture, and others interested in the properties and uses of wood. Lectures, recitations, and laboratory work. Three hours, fall and winter.

6. Exploitation. Methods and means employed in the harvest of forest products, logging, transportation, milling, and preparation of wood for market. Lectures and recitations. Three hours, winter term. Excursions to actual operations and points of manufacture.

7. Forest mensuration. Methods of ascertaining volume of felled and standing trees, of whole forest growths, timber estimating, determining accretion of trees and stands. Lectures, recitations, and field work. Three hours, winter and spring.

8. Forest regulation. Principles and methods underlying the preparation of plans of management for continuous wood and revenue production. Lectures and recitations. Four hours, fall term. Field work in summer.

9. Forest administration. Organizing a forestry service, manner of employing and supervising labor, business methods as applied to forest management. Lectures and recitations. Two hours, spring term.

10. Forest valuation. Principles and methods of ascertaining the money value of forest growths at different ages for purposes of sales, exchanges, damage suits, etc. Lectures. Two hours, spring term.

11. Forestry statics and finance. Application of the principles of finance to forest management; methods of finding the most profitable form of management, determining rotation and expenditures with reference to revenue. Lectures and recitations. Three hours, winter term.

12. Forestry history and politics. Historical development of the economic and technical features of modern forestry; forestry conditions at home and abroad; forests and forestry as factors in the household of the community and nation; basis and principles underlying forest policies of the State. The course will prove of value and interest to students of political economy. Lectures only. Two hours, winter and spring.

The only other institutions in the country which have given any attention to instruction in forestry heretofore have been the land-grant colleges of the several States. Of these, twenty-two have offered courses varying in length from a brief series of lectures to two full terms' work. These are the agricultural colleges of Alabama, Arkansas, Connecticut, Iowa, Idaho, Kansas, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, North Dakota, Ohio, Pennsylvania, Rhode Island, South Dakota, Texas, Vermont, Washington, and West Virginia. Nine colleges touch upon forestry incidentally in connection with instruction in other branches, such as botany and horticulture, namely, those of Virginia, North Carolina, Georgia, Mississippi, Colorado, Oklahoma, Indiana, and Maine. Ten institutions report no reference to the subject whatever. As to the character of the instruction in the courses in forestry, it varies greatly in the several institutions. The usual purpose is to give the students a general idea of the influence of forests upon climate and water flow and of forest geography, with more specific training in identification of trees and in propagation and planting.

It is evident that considered as a part of a general course in agriculture it is not feasible or desirable to make forestry the major subject, as is necessary in a technical school; but the brief courses offered in the agricultural colleges have been very successful in promoting public interest in forest protection and silviculture.

In 1895 there were introduced into Congress two bills providing for forestry education, one (H. R. 8389) providing an appropriation of $5,000 to each of the agricultural colleges, to be devoted either to instruction or providing object-lessons in the field; the other (H. R. 8390) providing for a post-graduate school—a national school of forestry—in connection with the Department of Agriculture and its Division of Forestry.

No action beyond hearings before the Committee on Agriculture, to which the bills were referred, resulted.

FEDERAL FOREST POLICY.

The most important development in establishing a forest policy in the United States has been the change in the disposition of its public timber lands as a result of the educational campaign of the American Forestry Association. This association in 1888 presented a comprehensive bill, drawn by the chief of the Division of Forestry, providing for the withdrawal from entry or sale of all public timber lands not fit for agricultural use, and for their proper administration under technical advice (S. 1476 and S. 1779, Fiftieth Congress, first session).

Modifications of this bill were introduced from year to year and their enactment urged. In

the Fifty-first Congress, through the earnest insistence of Secretary of the Interior John W. Noble, who was fully imbued with the necessity of some action such as was advocated by the association, the following section was added to the act entitled "An act to repeal timber-culture laws, and for other purposes," approved March 3, 1891:

SEC. 24. That the President of the United States may, from time to time, set apart and reserve, in any State or Territory having public lands bearing forests, any part of the public lands wholly or in part covered with timber or undergrowth, whether of commercial value or not, as public reservations, and the President shall, by public proclamation, declare the establishment of such reservations and the limit thereof.

Acting upon this authority, Presidents Cleveland and Harrison established seventeen forest reservations, with a total estimated area of 17,500,000 acres previous to 1894.

These forest reservations, together with the national parks which were established before, to be sure for quite different purposes, made thus the forest lands reserved by the Government aggregate over 20,000,000 acres as follows:

No.[a]	Forest reservations.	Established.	Area.
			Acres.
1	Yellowstone National Park timber-land reserve (Wyo.)	Sept. 10, 1891	1,239,040
2	White River Plateau timber-land reserve (Colo.)	Oct. 16, 1891	1,198,080
3	Pecos River forest reserve (N. Mex.)	Jan. 11, 1892	311,040
4	Sierra forest reserve (Cal.)	Feb. 14, 1893	4,096,000
5	Pacific forest reserve (Wash.)	Feb. 20, 1893	967,680
6	Pikes Peak timber-land reserve (Colo.)	Mar. 18, 1892	184,320
7	Bull Run timber-land reserve (Oreg.)	June 17, 1892	142,080
8	Plum Creek timber-land reserve (Colo.)	June 23, 1892	179,200
9	South Platte forest reserve (Colo.)	Dec. 9, 1892	683,520
10	San Gabriel timber-land reserve (Cal.)	Dec. 29, 1892	555,520
11	Battlement Mesa forest reserve (Colo.)	Dec. 24, 1892	858,240
12	Afognak forest and fish culture reserve (Alaska)	do	Unknown.
13	Grand Canyon forest reserve (Ariz.)	Feb. 20, 1893	1,851,520
14	Trabuco Canyon forest reserve (Cal.)	Feb. 25, 1893	49,920
15	San Bernardino forest reserve (Cal.)	do	737,280
16	Ashland forest reserve (Oreg.)	Sept. 28, 1893	18,560
17	Cascade Range forest reserve (Oreg.)	do	4,492,800
	Total acreage of forest reserves		17,564,800
	NATIONAL PARKS.		
18	Yellowstone National Park	Mar. 1, 1872	2,142,720
19	Yosemite National Park	Oct. 1, 1890	967,680
20	Sequoia National Park	do	161,280
21	General Grant National Park	do	2,560

[a] The numbers refer to those used on map, Plate II.

The reservations were established usually upon the petition of citizens residing in the respective States and after due examination, the forestry association acting as intermediary.

Meanwhile the legislation devised for the administration of the forest reserves, existing or to be established, specially urged by Representative McRae, chairman of Public Lands Committee, failed to be enacted, although in the Fifty-third Congress it was passed by both Houses, but failed in conference.

Secretary Hoke Smith, of the Department of the Interior, impressed with the importance of devising some adequate system of protection and management of the forests, both within the reserves and in the public domain, and urged by the committee of the Forestry Association, under date of February 15, 1896, requested the National Academy of Sciences, the legally constituted adviser of the Government in scientific matters, to investigate and report "upon the inauguration of a rational forest policy for the forested lands of the United States." He especially desired an official expression as to the desirability and practicability of preserving the forests from fire and maintaining as forested lands portions of the public domain now bearing wood growth; as to how far the influence of forests on climate, soil, and water conditions warranted a policy of forest conservation in regions where the public domain is principally situated; and what specific legislation should be enacted to remedy existing evils.

Under date of February 1, 1897, the academy submitted to Secretary Francis a preliminary report recommending the creation of thirteen additional forest reserves with a total area of 21,379,840 acres. These reserves were proclaimed, as recommended, by the President February 22, 1897. On May 1, 1897, the president of the academy submitted his complete report, embodying

a comprehensive review of the subject, with recommendations and bills for the establishment of a bureau of forestry in the Department of the Interior. This report has been printed as Senate Document No. 105.

The following forest reservations were created, upon the recommendation of the committee of the National Academy of Sciences, their status as to final extent and retention as reserves being still in doubt:

	Acres.
1. Black Hills Reserve in South Dakota	967,680
2. Big Horn Reserve in Wyoming	1,198,080
3. Teton Forest Reserve in Wyoming	829,440
4. Flathead Forest Reserve in Montana	1,382,400
5. Lewis and Clarke Forest Reserve in Montana	2,926,080
6. Priest River Forest Reserve in Idaho and Washington	645,120
7. Bitter Root Forest Reserve in Montana and Idaho	4,147,200
8. Washington Forest Reserve in Washington	3,594,240
9. Olympic Forest Reserve in Washington	2,188,800
10. Mount Rainier Forest Reserve in Washington	1,267,200
11. Stanislaus Forest Reserve in California	691,200
12. San Jacinto Forest Reserve in California	737,280
13. Utah Forest Reserve	705,120
Total estimated area	21,379,840

The sundry civil appropriation bill passed June 4, 1897 (see Senate Doc. No. 102), set aside the proclamations of February 22, 1897, suspending the reservations, which were made upon the recommendation of the committee of the academy, until March 1, 1898, presumably to give time for the adjustment of private claims and to more carefully delimit the reservations, an appropriation of $150,000 for the survey of the reservations under the supervision of the Director of the Geological Survey being made. The provisos attached to this appropriation embody the most important forestry legislation thus far enacted by Congress. These provisos had been in the main formulated in a bill known as the McRae bill (H. R. 119), which was passed by the House of Representatives and the Senate of the Fifty-third Congress—without, however, becoming a law; and again had passed the House in the Fifty-fourth Congress, it being the legislation advocated by the American Forestry Association as a first step toward a more elaborate forest administration of the public timber lands. Excluding minor items, the law provides that—

All public lands heretofore designated and reserved by the President of the United States under the provisions of the act approved March third, eighteen hundred and ninety-one, the orders for which shall be and remain in force and effect, unsuspended and unrevoked, and all public lands that may hereafter be set aside and reserved as public forest reserves under said act, shall be as far as practicable controlled and administered in accordance with the following provisions:

"No public forest reservation shall be established, except to improve and protect the forest within the reservation, or for the purpose of securing favorable conditions of water flow, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States; but it is not the purpose or intent of these provisions or of the act providing for such reservations to authorize the inclusion therein of lands more valuable for the mineral therein or for agricultural purposes than for forest purposes.

"For the purpose of preserving the living and growing timber and promoting the younger growth on forest reservations, the Secretary of the Interior, under such rules and regulations as he shall prescribe, may cause to be designated and appraised so much of the dead, matured, or large growth of trees found on such forest reservations as may be compatible with the proper utilization of the forests thereon, and may sell the same for not less than the appraised value in such quantities to each purchaser as he shall prescribe, to be used in the State or Territory in which such timber reservation may be situated, respectively, but not for export therefrom. Before such sale shall take place, notice thereof shall be given by the Commissioner of the General Land Office for not less than sixty days, by publication in a newspaper of general circulation, published in the county in which the timber is situated, if any is therein published, and if not, then in a newspaper of general circulation published nearest to the reservation, and also in a newspaper of general circulation published at the capital of the State or Territory where such reservation exists; payments for such timber to be made to the receiver of the local land office of the district wherein said timber may be sold, under such rules and regulations as the Secretary of the Interior may prescribe; and the moneys arising therefrom shall be accounted for by the receiver of such land office to the Commissioner of the General Land Office in a separate account, and shall be covered into the Treasury. Such timber, before being sold, shall be marked and designated, and shall be cut and removed under the supervision of some person appointed for that purpose by the Secretary of the Interior, not interested in the purchase or removal of such timber nor in the employment of the purchaser thereof. Such supervisor shall make a report in writing to the Commissioner of

the General Land Office and to the receiver in the land office in which such reservation shall be located of his doings in the premises.

"Upon the recommendation of the Secretary of the Interior, with the approval of the President, after sixty days' notice thereof, published in two papers of general circulation in the State or Territory wherein any forest reservation is situated and near the said reservation, any public lands embraced within the limits of any forest reservation which, after due examination by personal inspection of a competent person appointed for that purpose by the Secretary of the Interior, shall be found better adapted for mining or for agricultural purposes than for forest usage, may be restored to the public domain. And any mineral lands in any forest reservation which have been or which may be shown to be such, and subject to entry under the existing mining laws of the United States and the rules and regulations applying thereto, shall continue to be subject to such location and entry, notwithstanding any provisions herein contained."

The law authorizes the Secretary of the Interior to permit the use of timber and stone by bona fide settlers, miners, etc., for firewood, fencing, buildings, mining, prospecting, and other domestic purposes. It protects the rights of actual settlers within the reservations, empowers them to build wagon roads to their holdings, enables them to build schools and churches, and provides for the exchange of such for allotments outside the reservation limits. The State within which a reservation is located maintains its jurisdiction over all persons within the boundaries of the reserve.

Under the above enactment, the Commissioner of the General Land Office has formulated rules and regulations for the forest reservations, and a survey of the reserves last proclaimed is being made by the United States Geological Survey, the appropriations for such a survey having been continued for the year 1898; and the date for the segregation of agricultural lands and their return to the public domain open for entry having been deferred.

The appointment of forest superintendents, rangers etc., although not with technical knowledge, to take charge of the reservations marks the beginning of a settled policy of the United States Government to take care of its long-neglected forest lands.

In this connection it will be interesting to show that the agitation for rational treatment of the public-timber domain is by no means of recent date, but may be said to celebrate this very year its silver jubilee. A quarter century ago exactly the first true forestry bill was introduced by Mr. Haldeman in the Forty-second Congress and was lost. It provided that in the disposal of the public domain the condition be inserted into the patents that 10 per cent of the land shall be kept in timber, or, if not timbered, shall be planted to timber.

The subjoined table exhibits the long struggle for some kind of legislation; the failure of the numerous bills introduced, and the inactivity of committees and legislatures. It was originally printed in Bulletin 2 of the Division of Forestry, Department of Agriculture, in 1887, and has been here brought up to date.

It will be seen that hardly any kind of legislation which could be suggested has been overlooked, from the creation of forest commissions to investigate the subject to providing for fully organized forest administrations and the establishment of forestry schools.

The earliest action of the General Government having regard to the preservation of timber was in 1799, when Congress appropriated $200,000 for "the purchase of growing or other timber, or of lands on which timber is growing, suitable for the Navy, and for its preservation for future use." The special object of this legislation was to secure a supply of live-oak timber, which was considered peculiarly valuable for shipbuilding, and was in great demand for that purpose, both at home and abroad, while its growth was confined to a limited portion of our territory in the vicinity of the Gulf. Two small islands on the coast of Georgia, containing together about 2,000 acres, were purchased under the act of 1799. Another act (Rev. Stat., sec. 2458), having the same object in view, was passed in 1817, by which the Secretary of the Navy was directed to cause lands producing live oak or red cedar to be explored, and to have selections made of tracts necessary to furnish for the Navy a sufficient supply of such timbers. Under this act 19,000 acres in Louisiana, which had recently become ours by purchase from France, were reserved.

Additional enactments were made in 1820 and 1827, by which the selection of lands to be reserved was intrusted to the surveyor of public lands in place of agents appointed by the Secretary of the Navy, and the President was authorized to withhold such lands from sale.

In 1822 an act was passed (Rev. Stat., sec. 2460) authorizing the President to employ the land and naval forces, so far as necessary, effectually to prevent the felling or other destruction

of timber in Florida, and to take such other measures as might be deemed advisable for the preservation of timber there. (Florida had recently been ceded to the United States by Spain, and was known to abound in live-oak timber.)

In 1831 an act was passed (Rev. Stat., secs. 2461, 2462, and 2463) of wider scope than that of 1822. This made it a felony, with penalty of fine and imprisonment, to cut or remove timber from any of the public lands, whether reserved or not, except for the use of the Navy, and subjected any vessel transporting such timber without proper authority and for any other purpose than for the use of the Navy, to confiscation, and the master of the vessel to a fine.

This act is the one under which, up to the present time, all the protection they have had has been secured to the public forests, the Supreme Court having construed the act (9 How., 351) as authorizing the protection of all timber on the public lands and punishment for trespass upon the same. Under the act of 1831 the Treasury Department undertook a partial oversight and protection of timber on the public lands through its ordinary agents. In 1855 this oversight was transferred to agents of the Land Department, registers and receivers being instructed to act also as timber agents, but without any additional compensation. Where trespass was willfully committed, payment of stumpage was demanded or the timber was seized and sold and the proceeds paid into the Treasury. Where the trespass was committed ignorantly, actual entry of the land only was required, with payment of the usual entry charges.

The first appropriation for the payment of agents specially employed for the protection of timber on the public lands was made in 1872, when $5,000 were appropriated. A like sum was appropriated annually thereafter for five years. In 1878, to meet expenses for suppressing depredations upon timber on the public lands, $25,000 were appropriated, and subsequently these appropriations were increased until in 1893 they reached the limit of $120,000, then to be reduced to $40,000, $60,000, and $90,000, for 1894, 1895, and 1896 respectively.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1871	41st, 3d sess	H. R. 2930	For the sale of timber lands in California and Oregon	Referred to Committee on Public Lands.
1871	....do	H. R. 3005	To authorize the sale of timber lands in California, Oregon, and Washington Territory, not exceeding 640 acres to one person or association, without residence, at $2.50 per acre.	Passed in House. In Senate, referred to Committee on Public Lands.
1871	42d, 1st sess	H. R. 274	....do	Referred to Committee on Public Lands.
1872	42d, 2d sess	H. R. 2197	To encourage the planting of trees and the preservation of woods on the public domain. (The first real and comprehensive forestry bill.)	Referred to Committee on Agriculture. Reported favorably. Failed of passage—81 yeas, 87 nays.
1872	....do		Resolution that the Committee on Agriculture inquire whether a certain percentage of each quarter section of public lands sold must be planted with trees or a certain percentage of existing forests preserved for the purpose of preventing or remedying drouth.	No action.
1873	43d, 1st sess	H. R. 410	Same as Garfield bill (274) above	Referred to Committee on Public Lands. June 3, reported back with amendments and recommitted. December, 1874, H. R. bill 4194 reported by committee as substitute. Passed February 22, 1875. In Senate, February 22, referred to Committee on Public Lands.
1874	43d, 1st sess	Senate 471	For the survey and disposal of the timber lands of the United States. Miners may buy stumpage, not more than 160 acres, till that is cut, at $2.50 per acre. Homesteaders may buy 40 acres of timber land near agricultural land at same price.	Referred to Committee on Public Lands. Reported with amendments.
1874	....do	H. R. 2497	For the appointment of a commission for inquiry into the destruction of forests and into the measures necessary for the preservation of timber.	Referred to Committee on Public Lands. Reported back with H. R. 2540 as a substitute.
1874	....do	H. R. 2540	For the appointment of a commission to inquire into the destruction of forests and into the measures necessary for the preservation of timber.	Reported by Committee on Public Lands as a substitute for preceding bill, H. R. 2497.
1875	43d, 2d sess	H. R. 4430	To regulate the survey and sale of the timber lands of the United States. Commissioner of the Land Office to survey and appraise lands more valuable for their timber than for agricultural use. Such lands not to be entered under homestead or preëmption laws, but appraised and offered at public sale, and if not sold then to be open to private entry at a price not less than the appraisal.	Referred to Committee on Public Lands.
1875	44th, 1st sess	H. R. 323	To regulate the survey and sale of the timber lands of the United States. Same bill as the preceding.	Do.
1875	....do	Senate 2	To repeal section 2303 of the Revised Statutes, thereby opening timber lands in Southern States to private entry in unlimited quantities and at the reduced price of $1.25 per acre.	Referred to Committee on Public Lands. Reported back and passed. In House referred to Committee on Public Lands. Passed House and became a law July 4, 1876, through inaction of the President.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1875	44th, 1st sess	Senate 6	For sale of timber lands in California, Oregon, and the Territories. Same as previous bills with similar title.	Referred to Committee on Public Lands. Passed Senate February, 1876. In House February, 1876, referred to Committee on Public Lands. March, 1877, House refused to suspend rules and pass the bill.
1876	do	H. R. 660	For the sale of the timber lands in the Territories. Lands valuable for timber, but not for cultivation, to be sold at $2.50 per acre, not more than 40 acres to one person.	Referred to Committee on Public Lands.
1876	do	H. R. 1191	To regulate the survey and sale of the timber lands of the United States. Lands valuable chiefly for timber not to be subject to entry under preemption or homestead laws, but to be appraised and sold at not less than the appraised value.	Referred to Committee on Public Lands. Reported with amendments and recommitted.
1876	do	H. R. 1310	For the appointment of a commission, etc. Same as preceding bill (H. R. 2540).	Referred to Committee on Public Lands. No opportunity was afforded for regular action on the bill, but, on motion of Mr. Dunnell, the substance of it was added as an amendment to the general appropriation bill, and became a law August, 1877.[a]
1876	do	H. R. 2075	For the preservation of the forests adjacent to the sources of navigable rivers and other streams. Such timber lands to be withdrawn from sale and a commission to determine what should be reserved so as to prevent scanty supply of water.	Referred to Committee on Public Lands.
1877	45th, 1st sess	H. R. 797	For the sale of timber lands in the Territories. Same as bill (H. R. 660) in Forty-fourth Congress.	Do.
1877	do	H. R. 1154	To regulate the survey and sale of timber lands of the United States. Same as bills in the Forty-third and Forty-fourth Congresses.	Do.
1877	do	H. R. 1525	To put into market certain timber lands of the United States. Declaring subject to entry, in any quantity, all public timber lands in Alabama, Louisiana, and Minnesota which have been subject to entry in limited quantities for twenty years, and after entry of such lands to be no prosecution for trespass or timber cutting.	Do.
1878	45th, 2d sess	H. R. 2658	To provide for the entry of unsurveyed timber lands. Allowing the owner of a mine to take 160 acres of timber land for every 20 acres of mineral land owned by him, and the owner of agricultural land 40 acres for every quarter section, and for every $20,000 expended on a mill or furnace 640 acres may be taken at $2.50 per acre.	Do.
1878	do	H. R. 3981	Withdrawing lands chiefly valuable for timber from entry under preëmption or homestead laws. Such lands to be surveyed and divided into "timber lands" and "mineral timber lands." On the latter the timber only to be sold. Timber lands to be appraised and sold by commissioners. Such lands as are needed for irrigation purposes to be withheld from sale.	Reported by Committee on Public Lands as a substitute for several bills. Recommitted.
1878	do		$25,000 appropriated to suppress depredations on public timber.	
1878	do	Senate 926	Allowing sale of timber lands unfit for cultivation in California, Oregon, Nevada, and Washington Territory at $2.50 per acre. No one person or association to enter more than 160 acres.	Referred to Committee on Public Lands. Passed Senate. Reported to and passed House. Approved by President June 3.
1878	do	H. R. 3800	Bill similar to next below	Referred to Committee on Public Lands.
1878	do	Senate 20	Allowing residents of Colorado, Nevada, and other Territories and all mineral districts to fell and remove, for building and other domestic purposes, trees on mineral lands.	Referred to Committee on Public Lands. Amended and passed by Senate. Passed House and signed by President June 3.
1879	45th, 3d sess	H. R. 6087	To regulate the survey and sale of timber lands. Same as bill presented December, 1875 (H. R. 323), providing that timber lands more valuable for lumber than for agricultural purposes be reserved from entry under homestead or preemption laws, appraised, and sold to highest bidder, but not for less than appraisement.	Referred to Committee on Public Lands.
1879	46th, 1st sess	H. R. 1164	To regulate the survey and sale of timber lands of the United States. Same as last bill above.	Do.
1880	46th, 2d sess	H. R. 6321	To prevent depredations upon timber in the Indian Territory.	Referred to Committee on Indian Affairs.
1880	do	H. R. 6430	Authorizing citizens of Colorado, Nevada, and the Territories, to fell and remove timber on the public domain, for mining and domestic purposes. Extending the act of June, 1878.	Referred to Committee on Public Lands.
1880	do	Senate 1812	To prevent depredations upon timber on Indian reservations.	Reported from the Committee on Indian Affairs.
1880	do	H. R. 6371	To prevent depredations upon timber on the Indian reservations. Same as last bill above.	Referred to Committee on Indian Affairs.
1880	do	H. R. 1846	Act condoning trespass on public lands prior to March, 1879. Persons against whom suits were pending prior to that date to enter lands trespassed upon and pay accrued costs, thereupon suits to be discontinued. At same time price to be paid for lands to be reduced from $2.50 to $1.25.	Approved by the President June 15, 1880.
1882	47th, 1st sess	Senate 760	For the classification of the public lands in Colorado and the sale of timber thereon. The Secretary of the Interior to regulate the sale, and reserve timber on head waters of streams and on mountains.	Referred to Committee on Public Lands.

[a] By this enactment the Commissioner of Agriculture was directed to appoint a competent person to make the contemplated inquiries and investigations.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1882	47th, 1st sess	Senate 1641	To amend act of 1878, so as to allow any one in Western States and Territories to remove timber from mineral lands for any purpose, under rules and regulations of the Secretary of the Interior and payment of $2.50 per acre for the timber. No timber to be cut by mill owners or lumber manufacturers.	Referred to Committee on Public Lands.
1882	....do	Senate 1826	For the preservation of woods and forests adjacent to sources of navigable rivers. Same as bill introduced in House, First session, Forty-fourth Congress.	Referred to Committee on Agriculture.
1882	....do	H. R. 6315	For the preservation of woods, etc. Same as Senate bill next above.	Do.
1882	47th, 2d sess	H. R. 6997	To provide for the classification and disposition of pine-timber lands. Such lands, chiefly valuable for their timber, not to be subject to preëmption or homestead entry, but to be appraised by the Secretary of the Interior, and sold from time to time at public sale, for not less than two-thirds the appraisement. Mineral lands exempt from the act.	Referred to Committee on Public Lands.
1883	....do	H. R. 7509	To regulate the sale of the timber lands of the United States. Similar to last bill above, but lands remaining unsold to be subject to private entry at the appraised value.	Do.
1883	....do	Senate 2496	For the protection and preservation of the forests of the United States. One hundred thousand dollars to be appropriated to Colorado for the establishment of an experiment station under the direction of the Department of Agriculture.	Referred to Committee on Appropriations.
1883	....do	H. R. 4757	Act to exclude the public lands in Alabama from the operation of laws relating to mineral lands. (In reality an act to sell all mineral lands in Alabama as agricultural lands, at private sale, in unlimited quantities, and at the reduced rate of $1.25 per acre, to citizens or aliens.)	Approved by the President March 3, 1883.
1883	48th, 1st sess	H. R. 832	For the classification and disposition of pine-timber lands. Same as above bill presented in Forty-seventh Congress.	Referred to Committee on Public Lands.
1883	....do	Senate 1258	For the preservation of woods and forests adjacent to sources of navigable rivers, etc. Same as bill in Forty-seventh Congress.	Referred to Committee on Agriculture.
1883	....do	H. R. 4811	....do	Do.
1883	....do	H. R. 5206	....do	Do.
1884	....do	Senate 1544	To prevent cutting of timber on military or Indian reservations.	Referred to Committee on Indian Affairs. Passed in Senate April 23; in House of Representatives referred to Committee on Indian Affairs.
1884	....do	Senate 1188	For the protection, preservation, and extension of the forests of the United States. To establish an experiment station in connection with the Department of Agriculture west of the Mississippi River. To propagate and distribute forest trees, investigate qualities, time of growing, profit, etc. One hundred thousand dollars appropriated.	Referred to Committee on Agriculture and Forestry.
1884	....do	Senate 1824	Act to establish a forest reservation on the head waters of the Missouri and Columbia Rivers.	Passed Senate June, 1884. In House printed.
1884	48th, 2d sess	Senate 2451	For the protection of forests on the public domain. Withdraws all timber land from sale under existing laws. Forest commission to be appointed to examine and classify forest lands and determine what should be permanently reserved. Timber on reserved lands to be sold under direction of the Commissioner of the Land Office.	Referred to Committee on Agriculture. Reported favorably.
1885	49th, 1st sess	Senate 581	To establish a forest reservation in Montana. Same as bill S. 1824, in Forty-eighth Congress.	Referred to Committee on Agriculture. Reported favorably. Passed Senate. In House on calendar.
1885	....do	H. R. 379	To repeal act of 1878 for the sale of timber lands in California, Oregon, Nevada, and Washington Territory.	Referred to Committee on Public Lands.
1885	....do	H. R. 2946	For the preservation of woods and forests adjacent to sources of navigable rivers, etc. Same as bill offered in Forty-eighth Congress.	Referred to Committee on Agriculture.
1885	....do	Senate 551	....do	Do.
1886	....do	H. R. 5556	To define and punish the offense of setting fire to woods or forests belonging to the United States.	Referred to Committee on Judiciary. Reported at second session, with amendments, and placed on the Calendar.
1887	49th, 2d sess	H. R. 10430	For the protection of forests in California. To withdraw from sale Government forest lands in California not suited to agriculture. Such lands not to be alienated from the Government, but to be placed temporarily under the management of the forest commissioners of California. Fifty thousand dollars appropriated to carry out the act.	Referred to Committee on Public Lands. Reported favorably.
1888	50th, 1st sess	Senate 16	To set apart from the public domain in the State of Oregon, as a public park for the benefit of the people of the United States, townships 27, 28, 29, 30, and 31, in ranges 5 and 6 east of the Willamette meridian, in the State of Oregon.	Reported back adversely and indefinitely postponed.
1888	....do	Senate 196	To cancel certain reservations of lands on account of live oak in the southwestern land district of the State of Louisiana.	Referred to Committee on Public Lands. Reported back. Passed Senate. Referred to House Committee on Public Lands. Reported back. Amended and passed House. Senate concurs in House amendment. Examined and signed. Approved by President.
1888	....do	Senate 540	To establish a forest reservation on the headwaters of the Missouri River and the headwaters of Clarks Fork of the Columbia River.	Referred to Committee on Agriculture and Forestry.
1888	....do	Senate 596	For the preservation of the woods and forests of the national domain adjacent to the sources of the navigable rivers and their affluents in the United States.	Do.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1888	50th, 1st sess.	Senate 957	To establish a public park at Pagosa Springs, in the State of Colorado.	Referred to Committee on Public Lands. Reported back with amendments. Amended and passed Senate. Referred to House Committee on Public Lands.
1888	do	Senate 1476	For the protection and administration of the forests of the public domain.	Referred to Committee on Agriculture and Forestry.
1888	do	Senate 1779	do	Debated and referred to the Committee on Agriculture and Forestry.
1888	do	Senate 1817	To grant the State of Oregon townships 27, 28, 29, 30, and 31 south, in ranges 5 and 6 east of the Willamette meridian, in the State of Oregon, for a public park.	Referred to Committee on Public Lands. Reported back with amendment. Amended and passed Senate. Referred to House Committee on Public Lands.
1888	do	Senate 2427	To establish a public park to be called and known as the Royal Arch Park.	Referred to Committee on Public Lands. Reported back with amendments. Amended and passed Senate. Referred to House Committee on Public Lands.
1888	do	Senate 2510	To amend act authorizing citizens of Colorado, Nevada, and the Territories to fell and remove timber on the public domain for mining and domestic purposes.	Referred to Committee on Public Lands.
1888	do	Senate 2877	Authorizing citizens of Colorado, Nevada, and the Territories to fell and remove timber on the public domain for mining and domestic purposes.	Do.
1888	do	H. R. 1225	For the protection of forest lands belonging to the United States and California.	Do.
1888	do	H. R. 1256	To establish a public park at Pagosa Springs, Colo	Do.
1888	do	H. R. 1300	To repeal the timber-land act of June 3, 1878	Referred to Committee on Public Lands. Laid on table.
1888	do	H. R. 1353	To further amend the public-land laws, and for the preservation of natural forests on the public domain, the protection of water supply, and for other purposes.	Referred to Committee on Public Lands.
1888	do	H. R. 1982	To set apart a certain tract of land situated on the headwaters of the Pecos River, in New Mexico, as a public park.	Do.
1888	do	H. R. 3239	For the preservation of the woods and forests of the national domain adjacent to the sources of navigable rivers and their affluents in the United States.	Referred to Committee on Agriculture.
1888	do	H. R. 3279	To define and punish the offense of setting fire to and burning woods, grass, or forests on lands belonging to the United States.	Referred to Committee on Revision of Laws. Reported back.
1888	do	H. R. 3306	For the protection and the administration of the forests on the public domain.	Referred to Committee on Public Lands. Laid on table.
1888	do	H. R. 3410	For the preservation of the woods and forests of the national domain adjacent to the sources of the navigable rivers and their affluents in the United States.	Referred to Committee on Agriculture.
1888	do	H. R. 6045	For the protection and administration of the forests of the public domain.	Referred to Committee on Public Lands. Laid on table.
1888	do	H. R. 6709	To amend an act entitled "An act authorizing the citizens of Colorado, Nevada, and the Territories to fell and remove timber on the public domain for mining and domestic purposes," approved June 3, 1878.	Referred to Committee on Public Lands.
1888	do	H. R. 7001	To secure to actual settlers the public lands adapted to agriculture, to protect the forests on the public domain, and for other purposes.	Reported by Committee on Public Lands as a substitute for H. R. bill No. 6045 and other bills relating to the public lands. Passed. In Senate referred to Committee on Public Lands.
1888	do	H. R. 8006	To amend section 5388 of the Revised Statutes of the United States in relation to timber depredations.	Passed House. Referred to Senate Committee on Indian Affairs. Reported back. Passed Senate. Examined and signed. Approved by President.
1888	do	H. R. 9055	To establish a public park to be called and known as the Royal Arch Park.	Referred to Committee on Public Lands.
1888	do	H. R. 11037	To set apart a certain tract of land in the Territory of New Mexico as a public reservation.	Do.
1890	51st, 1st sess.	Senate 549	For the protection and administration of the forests on the public domain.	Referred to Committee on Agriculture and Forestry.
1890	do	Senate 1394	Authorizing the citizens of Colorado, North Dakota, South Dakota, Montana, Nevada, and the Territories to fell and remove timber on the public domain for mining and domestic purposes.	Referred to Committee on Public Lands.
1890	do	Senate 1523	For the preservation of the woods and forests of the national domain adjacent to the sources of the navigable rivers and their affluents in the United States.	Referred to Committee on Agriculture and Forestry.
1890	do	Senate 3199	To authorize the entry of the public lands by incorporated towns for cemetery and park purposes.	Referred to Committee on Public Lands.
1890	do	Senate 4156	For the protection of trees and other growth on the public domain from destruction by fire.	Introduced by Committee on Agriculture and Forestry. Debated, amended, and passed Senate. Referred to House Committee on Public Lands.
1890	do	H. R. 705	For the preservation of the woods and forests of the national domain adjacent to the sources of the navigable rivers and their affluents in the United States.	Referred to Committee on Public Lands.
1890	do	H. R. 4593	To amend an act entitled "An act for the sale of timber lands in the States of California, Oregon, and Nevada, and in Washington Territory," approved June 3, 1878.	Do.
1890	do	H. R. 5382	To dispose of the timber lands of the State of Arkansas at cash entry.	Do.
1890	do	H. R. 7026	For the reservation and preservation of forest lands on the public domain and to establish a commission to examine into the condition of the said lands, and to report a plan for their permanent management.	Do.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1890	51st, 1st sess	H. R. 8247	To authorize entry of the public lands by incorporated cities and towns for cemetery and park purposes.	Referred to Committee on Public Lands. Reported back. Passed House. Referred to Senate Committee on Public Lands. Reported back with amendment. Amended and passed Senate. House nonconcurs in Senate amendment. Conference appointed. Conference report made and agreed to. Examined and signed. Approved by President.
1890	do	H. R. 8459	For the protection of watersheds and irrigation systems and for the establishment of a forest administration on the Western mountains and plains.	Referred to Committee on Irrigation of Arid Lands in the United States.
1890	do	H. R. 10715	To provide for the sale of timber and stone lands and the timber thereon.	Referred to Committee on Public Lands.
1891	51st, 2d sess	H. R. 12750	To dispose of the timber lands of the State of Arkansas at cash entry.	Referred to Committee on Public Lands. Reported back.
1891	do	H. R. 13390	To amend "An act to set apart certain tracts of land in the State of California as forest reservations, approved October 1, 1890."	Do.
1892	52d, 1st sess	Senate 382	For the protection of trees and other growth on the public domain from destruction by fire.	Referred to Committee on Agriculture and Forestry. Reported back adversely and indefinitely postponed.
1892	do	Senate 664	For the sale of timber lands in the State of Montana, and to make the same subject to the mineral laws of the United States after their sale as timber lands.	Referred to Committee on Public Lands.
1892	do	Senate 2763	For the protection and administration of the public forest reservations.	Referred to Committee on Agriculture and Forestry. Reported back adversely and indefinitely postponed.
1892	do	Senate 3090	Providing for an experimental forestry tree-culture reserve.	Do.
1892	52d, 1st sess	Senate 3235	To provide for the establishment, protection, and administration of public forest reservations, and for other purposes.	Referred to Committee on Agriculture and Forestry. Reported back with amendments.
1892	do	H. R. 29	To dispose of the timber lands of the State of Arkansas at cash entry.	Referred to Committee on Public Lands. Laid on table.
1892	do	H. R. 102	To secure to actual settlers the public lands adapted to agriculture, to protect the forests on the public domain, and for other purposes.	Referred to Committee on Public Lands.
1892	do	H. R. 338	For the preservation of the woods and forests of the national domain adjacent to the sources of the navigable rivers and their affluents in the United States.	Referred to Committee on Agriculture.
1892	do	H. R. 2647	For the protection of trees and other growth on the public lands and on the public parks and reservations of the United States from destruction by fire.	Do.
1892	do	H. R. 5979	Regulating the manner and limitation of tree culture	Referred to Committee on Public Lands.
1892	do	H. R. 6656	To provide for the sale of stone and timber lands unfit for cultivation, and for other purposes.	Introduced by Committee on Public Lands as substitute for H. R. 5142 and H. R. 29. Laid on table.
1892	do	H. R. 8259	To dispose of the timber lands of the State of Arkansas at cash entry.	Referred to Committee on Public Lands.
1892	do	H. R. 8445	To repeal the act of October 1, 1890, in relation to forest reservations in California, and instructing the Secretary of the Interior to issue patents to settlers thereon.	Referred to Committee on Private Claims.
1892	do	H. R. 9709	To classify timber lands and provide for the sale of the timber thereon.	Referred to Committee on Public Lands.
1893	52d, 2d sess	Senate 2275	For the relief of purchasers of timber and stone lands under the act of June 3, 1878.	Passed House. Examined and signed.
1893	do	H. R. 9790	do	Referred to Committee on Public Lands.
1893	do	H. R. 9981	Reserving the timber reservation in Oklahoma Territory for the benefit of the Territorial institutions of learning.	Do.
1893	do	H. R. 10101	To protect public forest reservations	Referred to Committee on Public Lands. Reported back.
1893	do	H. R. 10207	To provide for the protection and administration of public forest reservations, and for other purposes.	Referred to Committee on Public Lands.
1894	53d, 1st sess	Senate 74	To provide for the classification and disposition of the public lands, the protection and administration of the public forest reservations, and for other purposes.	Do.
1894	do	Senate 672	Authorizing citizens of that part of the State of Washington eastward of the Columbia River to fell and remove timber on the public domain for mining and domestic purposes.	Do.
1894	do	H. R. 119	To protect public forest reservations	Referred to Committee on Public Lands. Reported back with amendments. Debated. Withdrawn.
1895	53d, 2d sess	Senate 2069	To amend the act of June 3, 1878, for the sale of timber and stone lands.	Referred to Committee on Public Lands.
1895	do	H. R. 119	To protect public forest reservations	Recommitted to Committee on Public Lands. Reported back with amendments. Resolution making bill special order reported, debated, and withdrawn.
1895	do	H. R. 4726	For the relief of citizens who have entered lands under an act entitled "An act for the sale of timber lands in California, Nevada, Oregon, and Washington Territory," approved June 3, 1878, and to amend said act and all acts amendatory thereof.	Referred to Committee on Public Lands. H. R. 7359 reported as substitute.
1895	do	H. R. 5714	To amend an act entitled "An act for the sale of timber land in the States of California, Oregon, Nevada, and Washington Territory."	Referred to Committee on Public Lands. Reported back. Debated.
1895	do	H. R. 7173	To provide for the reduction of the limits of Battlement Mesa Forest Reserve, in the State of Colorado.	Referred to Committee on Public Lands.
1895	do	H. R. 7259	For the relief of certain settlers who have entered lands under the timber and stone act, etc.	Introduced by Committee on Public Lands as substitute for H. R. 4726. Passed House. Referred to Senate Committee on Public Lands. Reported back.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1895	53d, 3d sess.	H. R. 7854	To prevent the free use of timber on the public lands and to revoke all permits heretofore granted in certain States, and for other purposes.	Referred to Committee on Public Lands. Reported back with amendment.
1895	...do	H. R. 7918	Authorizing bona fide settlers on public lands to cut timber therefrom, and for other purposes.	Referred to Committee on Public Lands.
1895	53d, 3d sess.	Senate 2571	To create a forestry commission	Referred to Committee on Forest Reservations.
1895	...do	H. R. 119	To protect public forest reservations	Debated in the House. Amended and passed House. Referred to Senate Committee on Public Lands. Reference changed to Committee on Forest Reservations. Reported back with amendment. Amended and passed Senate. Referred to House Committee on Public Lands. Conference appointed. Report made and withdrawn.
1895	...do	H. R. 7259	For the relief of certain settlers, who have entered lands under the timber and stone act, etc.	Passed Senate. Examined and signed.
1895	...do	H. R. 7854	To prevent the free use of timber on the public lands and to revoke all permits heretofore granted in certain States, and for other purposes.	Debated, amended, and passed House. Referred to Senate Committee on Public Lands.
1895	...do	H. R. 8323	Making an additional appropriation to meet the expenses of protecting the timber on the public lands for the fiscal year ending June 30, 1895.	Referred to Committee on Appropriations.
1896	54th, 1st sess.	Senate 914	To protect public forest reservations	Referred to Committee on Forest Reservations.
1896	...do	Senate 1214	To appropriate funds for investigations and tests of American timber.	Referred to Committee on Agriculture and Forestry.
1896	...do	Senate 1349	For the relief of applicants to purchase public lands under the timber and stone act.	Referred to Committee on Public Lands.
1896	...do	Senate 1632	To permit owners of claims to iron and coal mines on forest reservations of the United States to perfect their titles thereto, and to procure a patent therefor, and for other purposes.	Referred to Committee on Public Lands. Reported back with amendments. Amended and passed Senate. Referred to House Committee on Public Lands. Reported back with amendment.
1896	...do	Senate 1803	To repeal section 8 of an act entitled "An act to repeal timber-culture laws, and for other purposes," approved March 3, 1891.	Referred to Committee on Public Lands.
1896	...do	Senate 2118	To protect public forest reservations	Referred to Committee on Forest Reservations and Protection of Game. Reported back. Passed over in Senate.
1896	...do	Senate 2946	To protect and administer the public timber lands	Referred to Committee on Forest Reservations and Protection of Game.
1896	...do	Senate 2963	To amend sections 18, 19, 20, and 21 of the act entitled "An act to repeal timber-culture laws, and for other purposes," approved March 3, 1891.	Referred to Committee on Public Lands.
1896	...do	H. R. 14	For the relief of purchasers of timber and stone lands under the act of June 3, 1878.	Referred to Committee on Public Lands. Reported back adversely and laid on table.
1896	...do	H. R. 40	To prevent the free use of timber on the public lands for commercial use, and for other purposes.	Referred to Committee on Public Lands.
1896	...do	H. R. 119	To protect public forest reservations	Referred to Committee on Public Lands. Reported back with amendment. Passed House. Referred to Senate Committee on Forest Reservations and Protection of Game.
1896	...do	H. R. 832	To protect the forests on the public domain from destruction by fire.	Referred to Committee on Public Lands.
1896	...do	H. R. 2280	To open the forest reservations of the State of Colorado for the location of mining claims.	Referred to Committee on Public Lands. H. R. 4991 reported as substitute.
1896	...do	H. R. 4058	To set apart certain lands now known as the Pacific Forest Reservation as a public park, to be known as the Washington National Park.	Referred to Committee on Public Lands. Reported back with amendment. Amended and passed House. Referred to Senate Committee on Forest Reservations and Protection of Game.
1896	...do	H. R. 4065	For the relief of applicants to purchase public lands under the timber and stone act.	Referred to Committee on Public Lands.
1896	...do	H. R. 4067	To amend an act entitled "An act for the sale of timber lands in the States of California, Oregon, Nevada, and in Washington Territory," approved June 3, 1878.	Do.
1896	...do	H. R. 4336	To extend the mineral land laws of the United States to lands embraced within reservations created by Presidential proclamation, and for other purposes.	Referred to Committee on Indian Affairs.
1896	...do	H. R. 4442	To amend the act of June 3, 1878, entitled "An act for the sale of timber lands in the States of California, Oregon, Nevada, and in Washington Territory,' as amended by section 2 of the act of August 4, 1892.	Referred to Committee on Public Lands. Reported back.
1896	...do	H. R. 4562	To amend an act entitled "An act for the sale of timber lands in the States of California, Oregon, Nevada, and Washington Territory."	Referred to Committee on Public Lands.
1896	...do	H. R. 4991	To open forest reservations in the State of Colorado for the location of mining claims.	Introduced by Committee on Public Lands as substitute for H. R. 2280. Debated and passed House. Referred to Senate Committee on Public Lands. Reported back Passed Senate. Examined and signed. Approved by President.
1896	...do	H. R. 8730	To appropriate funds for investigations and tests of American timber.	Referred to Committee on Agriculture.
1896	...do	H. R. 9123	To prevent forest fires on the public domain	Referred to Committee on Public Lands. Reported back. Debated and passed House. Referred to Senate Committee on Public Lands.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1896	54th, 1st sess	H. R. 9124	To protect the forests on the public domain from destruction by fire.	Referred to Committee on Public Lands. Reported back.
1896	do	H. R. 9143	To protect public forest reservations	Referred to Committee on Public Lands.
1897	54th, 2d sess	Senate 1632	To permit owners of claims to iron and coal mines on forest reservations of the United States to perfect their title thereto, and to procure a patent therefor, and for other purposes.	Consideration in House objected to.
1897	do	Senate 2118	To protect public forest reservations	Passed over in Senate.
1897	do	H. R. 9124	To protect the forests of the public domain from destruction by firo.	Debated and rejected in House.
1897	do	H. R. 9123	To prevent forest fires on the public demain	Reported back and passed Senate Examined and signed. Approved by President.
1897	do	H. R. 9923	To confirm title to purchasers of certain lands under the timher and stone law.	Referred to Committee on Public Lands.
1897	do	H. R. 10270	Providing for the selection of lands in lieu of swamp lands included in forest reservations.	Do.
1897	do	H. R. 10356	To restore to tho public domain tho lands embraced within the forest reservations in the State of Wyoming set up and established by Executive order February 22, 1897.	Do.
1897	do	H. R. 4058	To set apart certain lands now known as the Pacific Forest Reserve as a public park, to be known as the Washington National Park.	Reported back. Passed Senate. Examined and signed.

To give a more complete view of the action of the Government in its bearings upon forestry, it seems proper to append to the foregoing synopsis the following record of legislation, actual as well as only proposed:

TIMBER-CULTURE ACTS.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1873	42d, 2d sess	Senate 680	To encourage the growth of timber on Western prairies. A person planting 40 acres of timher trees on Government land to be entitled to 160 acres at the expiration of 10 years. The so-called timher-culture act.	Referred to Committee on Public Lands. Reported favorably and passed. Approved March 3, 1873.
1874	43d, 1st sess	H. R. 743	To amend the above act. Confines privilege of entry to heads of families or persons over 21 years of age and to citizens of the United Statos. Reduces tho time for perfecting title to eight years. Restricts the amount to be entered by one person to 160 acres. Allows homesteaders to obtain patent by planting one-sixteenth of homestead with trees.	Passed and approved March 13, 1874.
1876	do	H. R. 2427	To amend act of 1873. Allows extension of time for perfecting title in case of the destruction of trees by grasshoppers; also permits seeds and nuts to be planted instead of trees.	Referred to Committee on Public Lands. Reported favorably. Passed and approved May 20, 1877.
1878	45th, 2d sess	H. R. 3235	To amend the act of 1873. Reducing the number of acres to be planted to 10 for every quarter section, and in the same proportion for smaller quantities, but requiring closer planting—2,700 trees per acre. Five acres to be broken first year and 5 the second, and planted with trees in the third and fourth years. Repeals the homestead provision of tho act of 1874.	Reported with amendments by committee. Passed and approved June 14, 1878.
1881	47th, 1st sess	H. R. 430	To amend the act of 1878. Specifying the kinds of trees to be planted.	Referred to Committee on Public Lands.
1882	do	H. R. 4497	To repeal the act of 1878	Do.
1885	49th, 1st sess	Senate 65	To repeal all laws for the preemption of public lands and those allowing entries for timher culture, the sale of desert lands, etc.	Do.
1885	do	H. R. 452	To repeal all laws for the preemption of public lands and those allowing entries for timber culture.	Do.
1885	do	H. R. 380	To repeal preemption and timber culture laws. Nearly identical with bill 452.	Do.
1886	do	H. R. 5210	To repeal all laws for the preemption of public lands and for timber-culture entries.	Do.
1886	do	H. R. 1238	To amend the act of 1878	Do.
1888	50th, 1st sess	Senate 2893	To amend an act entitled "An act to amend an act entitled 'An act to encourage the growth of timber on the Western prairies.'"	Do.
1888	do	H. R. 1301	To repeal all laws providing for the preemption of the public lands, the laws allowing entries for timber culture, the laws authorizing the sale of desert lands, and for other purposes.	Referred to Committee on Public Lands. Laid on table.
1888	do	H. R. 1601	To repeal all laws providing for the preemption of the public lands, the laws allowing entries for timber culture, and for other purposes.	Do.
1888	do	H. R. 2003	To repeal the preemption and timber-culture laws, and to amend the desert-land act, and for other purposes.	Do.
1890	51st, 1st sess	Senate 66	To repeal all laws providing for the preemption of the public lands, the laws allowing entries for timher culture, and for other purposes.	Referred to Committee on Public Lands. Reported back adversely and indefinitely postponed.
1890	do	Senate 366	To amend an act entitled "An act to amend an act entitled 'An act to encourage the growth of timber on the Western prairies.'"	Referred to Committee on Public Lands. Reported back. Passed Senate. Referred to House Committee on Public Lands.
1890	do	H. R. 84	To repeal all laws providing for the preemption of the public lands, the law allowing entries for timber culture and amending other land laws, and for other purposes.	Referred to Committee on Public Lands.

TIMBER CULTURE ACTS—Continued.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1890	51st, 1st sess	H. R. 550	To amend an act entitled "An act to amend an act entitled 'An act to encourage the growth of timber on the Western prairies.'"	Referred to Committee on Public Lands.
1890	....do	H. R. 5404	To provide for the commutation of timber-culture entries	Referred to Committee on Public Lands. H. R. 7254 reported as a substitute.
1890	....do	H. R. 5598	To repeal the timber-culture act	Referred to Committee on Public Lands.
1890	....do	H. R. 7254	To repeal the timber-culture laws, and for other purposes	Introduced by Committee on Public Lands as substitute for H. R. 5404. Debated and passed House. Reported back with amendment Debated, amended, and passed Senate. Referred to House Committee on Public Lands. House nonconcurs in Senate amendments. Conference appointed.
1891	51st, 2d sess	Senate 5129	To amend section 8 of an act approved Mar. 3, 1891, entitled "An act to repeal timber-culture laws, and for other purposes."	Passed Senate. Debated and passed House. Examined and signed. Approved by President.
1891	....do	H. R. 7254	To repeal timber-culture laws, and for other purposes	Conference report made. Debated and agreed to. Examined and signed. Approved by President.
1892	52d, 1st sess	Senate 1024	To amend chapter 561 of the laws of the second session of the 51st Congress entitled "An act to repeal timber-culture laws, and for other purposes."	Referred to Committee on Public Lands.
1892	....do	Senate 1179	To amend section 1 of an act approved Mar. 3, 1891, entitled "An act to repeal timber-culture laws, and for other purposes."	Referred to Committee on Public Lands. Reported back adversely and indefinitely postponed.
1892	....do	Senate 1248	To repeal section 24 of an act entitled "An act to repeal timber-culture laws, and for other purposes," approved Mar. 3, 1891.	Do.
1892	....do	Senate 2180	Declaring the construction of an act entitled "An act to repeal timber-culture laws, and for other purposes," approved Mar. 3, 1891.	Do.
1892	....do	Senate 3281	To amend section 7 of "An act to repeal timber-culture laws, and for other purposes," approved Mar. 3, 1891.	Referred to Committee on Public Lands.
1892	....do	Senate 3393	To amend an act approved March 3, 1891, entitled "An act to repeal timber-culture laws, and for other purposes."	Referred to Committee on Public Lands. Reported back with amendments.
1892	....do	H. R. 412	To amend section 1 of an act entitled "An act to repeal timber-culture laws, and for other purposes."	Referred to Committee on Public Lands. H. R. 7961 reported as substitute.
1892	....do	H. R. 7691	To amend an act entitled "An act to repeal timber culture laws, and for other purposes."	Introduced by Committee on Public Lands as substitute for H. R. 412. Debated.
1892	....do	H. R. 8702	To amend an act to repeal timber-culture laws, and for other purposes.	Referred to Committee on Public Lands.
1892	....do	H. R. 9003	To amend section 24 of "An act to repeal timber-culture laws, and for other purposes," approved Mar. 3, 1891.	Introduced by Committee on Public Lands as substitute for H. R. 2657.
1893	52d, 2d sess	Senate 2564	To amend section 6 of the act approved Mar. 3, 1891, entitled "An act to repeal timber-culture laws, and for other purposes."	Reported back.
1894	53d, 1st sess	Senate 113	To extend the provisions of "An act to amend section 8 of an act approved Mar. 3, 1891, entitled 'An act to repeal the timber-culture laws, and for other purposes,'" to all of that part of Oregon lying east of the Cascade range of mountains.	Referred to Committee on Military Affairs.
1894	....do	H. R. 1986	To amend section 6 of an act approved Mar. 3, 1891, entitled "An act to repeal timber-culture laws, and for other purposes."	Referred to Committee on Public Lands. Reported back. Passed House. Referred to Senate Committee on Public Lands. Reported back. Passed Senate. Examined and signed. Approved by President.
1895	53d, 2d sess	Senate 1281	To amend section 7 of "An act to repeal timber-culture laws, and for other purposes," approved Mar. 3, 1891.	Referred to Committee on Public Lands.
1895	....do	Senate 1696	To amend an act approved Mar. 3, 1891, entitled "An act to repeal timber-culture laws, and for other purposes."	Do.
1895	....do	H. R. 4458	To amend section 7 of "An act to repeal timber-culture laws, and for other purposes," approved Mar. 3, 1891.	Referred to Committee on Public Lands. Reported back.
1895	53d, 3d sess	....do	....do	Referred to House Committee on the Judiciary.
1895	....do	H. R. 8424	To amend the law relating to final proofs in timber-culture entries.	Referred to Committee on Public Lands.
1896	54th, 1st sess	Senate 103	Relating to final proof in timber-culture entries	Referred to Committee on Public Lands. Reported back with amendment; amended and passed Senate. Referred to House Committee on Public Lands. Reported back. Debated, amended, and passed House. Senate concurs in amendments. Examined and signed. Approved by President.
1896	....do	Senate 1378	To amend an act entitled "An act to repeal timber-culture laws, and for other purposes," approved Mar. 3, 1891.	Referred to Committee on Public Lands.
1896	....do	H. R. 2644	To amend the law relating to final proofs in timber-culture entries.	Do.
1896	....do	H. R. 3543	To amend the law relating to final proof in timber-culture entries.	Referred to Committee on Public Lands.
1896	....do	H. R. 4248	Granting to certain successful contestants of timber-culture entries the privilege of now exercising their right of entry under the timber-culture act of June 14, 1878.	Do.
1896	....do	H. R. 4694	To amend section 1 of the act of Mar. 3, 1891, entitled "An act to repeal timber-culture laws, and for other purposes."	Do.

TIMBER CULTURE ACTS—Continued.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1896	54th, 1st sess	H. R. 4959	To repeal section 8 of an act entitled "An act to repeal timber-culture laws and for other purposes," approved Mar. 3, 1819.	Referred to Committee on Public Lands.
1897	54th, 2d sess	Senate 3328	To amend an act entitled "An act to repeal the timber-culture laws, and for other purposes."	Referred to Committee on Public Lands. Reported back. Passed Senate. Referred to House Committee on Public Lands. Reported back with amendments. Debated, amended, and passed House. Senate concurs in House amendments. Examined and signed. Senate requests President to return bill. President complies with Senate request. Debated and referred to Senate Committee on the Judiciary. Committee discharged, bill reconsidered, and House amendments nonconcurred in. Conference appointed. Conference report made and agreed to. Examined and signed.
1897	54th, 2d sess	Senate 3689	To amend an act entitled "An act to repeal the timber-culture laws, and for other purposes."	Referred to Committee on Public Lands.
1897	do	H. R. 10314	do	Referred to Committee on Public Lands. Reported back.

FOR THE ESTABLISHMENT AND ENDOWMENT OF FORESTRY SCHOOLS.

1882	47th, 1st sess	Senate 1880	To aid in the endowment of a school of forestry at St. Paul. Granting 300 sections of public land for the purpose.	Referred to Committee on Agriculture.
1883	47th, 2d sess	H. R. 7440	To grant lands to Dakota for the purpose of establishing a school of forestry. Granting 400 sections of land for the purpose.	Referred to Committee on Public Lands.
1884	48th, 1st sess	H. R. 4361	To grant lands to Dakota for the purpose of establishing a school of forestry. Same bill as the preceding.	Do.
1886	49th, 1st sess	H. R. 2826	To grant lands to Dakota for the purpose of establishing a school of forestry. Same as two preceding bills.	Do.
1895	54th, 1st sess	Senate 793	To establish and maintain a national school of forestry	Do.
1895	do	H. R. 303	do	Do.

RECENT LEGISLATION.

[The following legislation was embodied in the sundry civil appropriation bill, which became a law in 1897. This law enables the Secretary of the Interior to formulate a plan for the proper administration of the forest reservations, but its provisions can hardly become operative without a sufficient appropriation to carry it into effect. Plans for the survey of the reserves, as provided in the following law, are now (June 24) about matured.]

AN ACT making appropriations for sundry civil expenses, etc., approved June 4, 1897.
(1897. Fifty-fifth Congress, first session.)

The sections of the bill referring to the forest reservations are as follows:

For the survey of the public lands that have been or may hereafter be designated as forest reserves by Executive proclamation, under section twenty-four of the act of Congress approved March third, eighteen hundred and ninety-one, entitled "An act to repeal timber-culture laws, and for other purposes," and including public lands adjacent thereto, which may be designated for survey by the Secretary of the Interior, one hundred and fifty thousand dollars, to be immediately available: Provided, That to remove any doubt which may exist pertaining to the authority of the President thereunto, the President of the United States is hereby authorized and empowered to revoke, modify, or suspend any and all such Executive orders and proclamations, or any part thereof, from time to time as he shall deem best for the public interests: Provided, That the Executive orders and proclamations dated February twenty-second, eighteen hundred and ninety-seven, setting apart and reserving certain lands in the States of Wyoming, Utah, Montana, Washington, Idaho, and South Dakota as forest reservations, be, and they are hereby, suspended, and the lands embraced therein restored to the public domain the same as though said orders and proclamations had not been issued: Provided, further, That lands embraced in such reservations, not otherwise disposed of before March first, eighteen hundred and ninety-eight, shall again become subject to the operations of said orders and proclamations as now existing or hereafter modified by the President.

The surveys herein provided for shall be made, under the supervision of the Director of the Geological Survey, by such person or persons as may be employed by or under him for that purpose, and shall be executed under instructions issued by the Secretary of the Interior; and if subdivision surveys shall be found to be necessary, they shall be executed under the rectangular system, as now provided by law. The plats and field notes prepared shall be approved and certified to by the Director of the Geological Survey, and two copies of the field notes shall be returned, one for the files in the United States surveyor-general's office of the State in which the reserve is situated,

the other in the General Land Office; and twenty photolithographic copies of the plats shall be returned, one copy for the files in the United States surveyor-general's office of the State in which the reserve is situated; the original plat and the other copies shall be filed in the General Land Office, and shall have the facsimile signature of the Director of the Survey attached.

Such surveys, field notes, and plats thus returned shall have the same legal force and effect as heretofore given the surveys, field notes, and plats returned through the surveyors-general; and such surveys, which include subdivision surveys under the rectangular system, shall be approved by the Commissioner of the General Land Office as in other cases, and properly certified copies thereof shall be filed in the respective land offices of the districts in which such lands are situated, as in other cases. All laws inconsistent with the provisions hereof are hereby declared inoperative as respects such survey: Provided, however, that a copy of every topographic map and other maps showing the distribution of the forests, together with such field notes as may be taken relating thereto, shall be certified thereto by the director of the survey and filed in the General Land Office.

All public lands heretofore designated and reserved by the President of the United States under the provisions of the act approved March third, eighteen hundred and ninety-one, the orders for which shall be and remain in full force and effect, unsuspended and unrevoked, and all public lands that may hereafter be set aside and reserved as public forest reserves under said act, shall be as far as practicable controlled and administered in accordance with the following provisions:

No public forest reservation shall be established except to improve and protect the forest within the reservation, or for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States; but it is not the purpose or intent of these provisions, or of the act providing for such reservations, to authorize the inclusion therein of lands more valuable for the mineral therein or for agricultural purposes than for forest purposes.

The Secretary of the Interior shall make provisions for the protection against destruction by fire and depredations upon the public forests and forest reservations which may have been set aside or which may be hereafter set aside under the said act of March third, eighteen hundred and ninety-one, and which may be continued; and he may make such rules and regulations and establish such service as will insure the objects of such reservations, namely, to regulate their occupancy and use and to preserve the forests thereon from destruction; and any violation of the provisions of this act or such rules and regulations shall be punished as is provided for in the act of June fourth, eighteen hundred and eighty-eight, amending section fifty-three hundred and eighty-eight of the Revised Statutes of the United States.

For the purpose of preserving the living and growing timber and promoting the younger growth on forest reservations, the Secretary of the Interior, under such rules and regulations as he shall prescribe, may cause to be designated and appraised so much of the dead, matured, or large growth of trees found upon such forest reservations as may be compatible with the utilization of the forests thereon, and may sell the same for not less than the appraised value in such quantities to each purchaser as he shall prescribe, to be used in the State or Territory in which such timber reservation may be situated, respectively, but not for export therefrom. Before such sale shall take place, notice thereof shall be given by the Commissioner of the General Land Office, for not less than sixty days, by publication in a newspaper of general circulation, published in the county in which the timber is situated, if any is therein published, and if not, then in a newspaper of general circulation published nearest to the reservation, and also in a newspaper of general circulation published at the capital of the State or Territory where such reservation exists; payments for such timber to be made to the receiver of the local land office of the district wherein said timber may be sold, under such rules and regulations as the Secretary of the Interior may prescribe; and the moneys arising therefrom shall be accounted for by the receiver of such land office to the Commissioner of the General Land Office in a separate account, and shall be covered into the Treasury. Such timber, before being sold, shall be marked and designated, and shall be cut and removed under the supervision of some person appointed for that purpose by the Secretary of the Interior, not interested in the purchase and removal of such timber nor in the employment of the purchaser thereof. Such supervisor shall make report in writing to the Commissioner of the General Land Office and to the receiver in the land office in which such reservation shall be located of his doings in the premises.

The Secretary of the Interior may permit, under regulations to be prescribed by him, the use of timber and stone found upon such reservations, free of charge, by bona fide settlers, miners, residents, and prospectors for minerals, for firewood, fencing, buildings, mining, prospecting, and other domestic purposes, as may be needed by such persons for such purposes; such timber to be used within the State or Territory, respectively, where such reservations may be located.

Nothing herein shall be construed as prohibiting the egress or ingress of actual settlers residing within the boundaries of such reservations, or from crossing the same to and from their property or homes; and such wagon roads and other improvements may be constructed thereon as may be necessary to reach their homes and to utilize their property, under such rules and regulations as may be prescribed by the Secretary of the Interior. Nor shall anything herein prohibit any person from entering upon such forest reservations for all proper and lawful purposes, including that of prospecting, locating, and developing the mineral resources thereof: Provided, That such persons comply with the rules and regulations covering such forest reservations.

That in cases in which a tract covered by an unperfected bona fide claim or by a patent is included within the limits of a public forest reservation, the settler or owner thereof may, if he desires to do so, relinquish the tract to the Government, and may select in lieu thereof a tract of vacant land open to settlement not exceeding in area the tract covered by his claim or patent; and no charge shall be made in such cases for making the entry of record or issuing the patent to cover the tract selected: Provided further, That in cases of unperfected claims the requirements

of the laws respecting settlement, residence, improvements, and so forth, are complied with on the new claims, credit being allowed for the time spent on the relinquished claims.

The settlers residing within the exterior boundaries of such forest reservations, or in the vicinity thereof, may maintain schools and churches within such reservation, and for that purpose may occupy any part of the said forest reservation, not exceeding two acres for each schoolhouse and one acre for a church.

The jurisdiction, both civil and criminal, over persons within such reservations shall not be affected or changed by reason of the existence of such reservations, except so far as the punishment of offenses against the United States therein is concerned; the intent and meaning of this provision being that the State wherein any such reservation is situated shall not, by reason of the establishment thereof, lose its jurisdiction, nor the inhabitants thereof their rights and privileges as citizens, or be absolved from their duties as citizens of the State.

All waters on such reservations may be used for domestic, mining, milling, or irrigation purposes, under the laws of the State wherein such forest reservations are situated, or under the laws of the United States and the rules and regulations established thereunder.

Upon the recommendation of the Secretary of the Interior, with the approval of the President, after sixty days' notice thereof, published in two papers of general circulation in the State or Territory wherein any forest reservation is situated, and near the said reservation, any public lands embraced within the limits of any forest reservation which, after due examination by personal inspection of a competent person appointed for that purpose by the Secretary of the Interior, shall be found better adapted for mining or for agricultural purposes than for forest usage, may be restored to the public domain. And any mineral lands in any forest reservation which have been or which may be shown to be such, and subject to entry under the existing mining laws of the United States and the rules and regulations applying thereto, shall continue to be subject to such location and entry, notwithstanding any provisions herein contained.

The President is hereby authorized at any time to modify any Executive order that has been or may hereafter be made establishing any forest reserve, and by such modification may reduce the area or change the boundary lines of such reserve, or may vacate altogether any order creating such reserve.

AN ACT making appropriations for sundry civil expenses, etc., approved June 30, 1898.

Protection and administration of forest reserves.—To meet the expenses of executing the provisions of the sundry civil act approved June fourth, eighteen hundred and ninety-seven, for the care and administration of the forest reserves, to meet the expenses of forest inspectors and assistants, and for the employment of foresters and other emergency help in the prevention and extinguishment of forest fires, and for advertising dead and matured trees for sale within such reservations: *Provided,* That forestry agents and supervisors, and other persons to be designated by the Secretary of the Interior for duty under this appropriation, shall be allowed per diem, subject to such rules and regulations as he may prescribe, in lieu of subsistence, at a rate not exceeding three dollars per day each, and actual necessary expenses for transportation, seventy-five thousand dollars.

That section eight of an act entitled "An act to repeal the timber-culture laws, and for other purposes," approved March third, eighteen hundred and ninety-one, be, and the same is hereby, amended as follows: That it shall be lawful for the Secretary of the Interior to grant permits, under the provisions of the eighth section of the act of March third, eighteen hundred and ninety-one, to citizens of Idaho and Wyoming to cut timber in the State of Wyoming west of the continental divide, on the Snake River and its tributaries, to the boundary line of Idaho, for agricultural, mining, or other domestic purposes, and to remove the timber so cut to the State of Idaho.

D. FOREST POLICIES OF EUROPEAN NATIONS.

The conditions which a hundred years ago influenced the policies of the European nations—namely, the necessity of looking out for continuance of domestic supplies—are at present well overcome, provided the supplies in other countries last and can readily be secured.

In regard to supplies, the European countries may be grouped into those which produce as yet more than they need, namely: Russia, Austria-Hungary, Servia, Sweden and Norway, which are, therefore, exporters; those which produce large quantities of forest products, but not sufficient for their needs, Germany, France, Switzerland; those which depend largely or almost entirely on importation, England, Belgium, Holland, Denmark, Spain, Portugal, Italy, Greece, and Turkey.

Nevertheless, at least in Germany, the desirability of fostering home production and advantages of a general economic character, especially employment of labor in winter time which the forest industries insure, have still an influence upon the policy of the Government, even with supply forests.

In this way may be explained the protective tariff against wood imports, which was enacted in 1885 and increased later, especially to keep out competition from the virgin woods of Austria-Hungary and Russia. The last revision of 1892 has for its object not the discouragement of importation, but the inducing of importation of only raw material to be manufactured at home, by imposing a duty five times as high on lumber as on logs.

The result, however, has been more satisfactory from the revenue point of view than in protecting the forest owners, the Austro-Hungarian railroads equalizing the duty charges by lower rates.

The existence of a State forest policy, such as most European States have adopted, is based at present mainly on the protective value of the forest cover and the recognition that private interest can not be expected, or is insufficent, to give proper regard to this feature in its treatment of the forest areas.

It can not be said that a finally settled policy exists in any of the States, not even in Germany, but only that it is in a highly advanced stage of formation, with the tendency of increasing governmental activity and interference.

Such a policy is expressed in various ways, State ownership, State supervision of communal and private forests, restriction of clearing and enforced reforesting, establishment of forestry schools, and experiment stations.

State ownership of forest areas, which in the beginning of the century began to decrease under the influence and misapplication of Adam Smith's teaching, and the doctrine of individual rights urged to its extreme consequences, is now on the increase in most States. Thus France, which during and after the Revolution, took the lead in this dismemberment of the forest property which the monarchy had maintained, sold during the years 1791 to 1795 nearly one-half of the State forests and continued to reduce the area until there remained in 1874 but one-fifth of the original holdings. Since then a reversal of the policy has been in practice, the area not only being increased but financial assistance in reforesting on a large scale being given to private owners and communities.

Thus in the budget for 1895 of $2,500,000 appropriated for the State forest department, $1,000,000 is set aside for the extension of the State forests and necessary improvement of the existing ones. The State owns about 2,600,000 acres—somewhat over 10 per cent of the total

area. In addition the private property is controlled entirely as regards clearing; that is to say, no clearing may be done without notice to the Government authorities, or, in the mountain districts, without sanction of the same.

This control is especially stringent with reference to the holdings of village and city corporations, which represent over 27 per cent of the forest area. These must submit their plans of management to the State forest department for approval, and are debarred from dividing their property, thus insuring continuity of ownership and conservative management.

The necessity for such control became apparent in the first quarter of the century, when as a consequence of reckless denudation in the Alps, Cévennes, and Pyrences, whole communities became impoverished by the torrents which destroyed and silted over the fertile lands at the foot of the mountains. Some 8,000,000 acres of mountain forest in twenty departments were involved in these disastrous consequences of forest destruction, with 1,000,000 acres of once fertile soil made useless. The work of recovery was begun under laws of 1860 and 1864, and a revised law, the reboisement act, of 1882. Under this law the State buys and recuperates the land, or else forces communities or private owners to do so with financial aid from the Government.

Since the operation of this law the State has spent in purchases of worn-out lands and in works to check the torrents and in reforesting, nearly $12,000,000, not including subventions to communities and private owners. It is estimated that $28,000,000 more will have to be expended before the area which the State does or is to possess, some 800,000 acres in all, will be restored.

A forestry school at Nancy educates the officers, and is among the best on the Continent.

England, in the home country, has had little need of a forest policy on account of its insular position and topography. Of the 3,000,000 acres of woodlands, mostly devoted to purposes of the chase or parks, 2 per cent are State forests, and so encumbered with rights of adjoining commoners as pasture or for wood supplies that no rational management is possible. But in India there is a well-organized forest administration with a very extensive area, namely, 60,000 square miles reserved and 34,590 square miles protected and under active control of the Government. The organization of the forestry service was begun in 1865 by German foresters. (See pages 259–263.) At present special schools of forestry, one in England and one in India, supply the technical education of the officers.

Italy has long suffered from the effects of forest devastation by droughts and floods, but the Government was always too weak to secure effective remedies. The State owns only 1.6 per cent of 116,000 acres of forest, the balance of 7,000,000 acres belonging to communities and corporations or individuals. Yet by the laws of 1877, revised in 1888, the policy of State interference is clearly defined. Excellent though the law appears on paper, it has probably not yielded any significant results or even general enforcement, owing to the financial disability of the Government. This law placed nearly half the area not owned by the State under Government control, namely, all woods and lands cleared of wood on the summits and slopes of the mountains above the upper limit of chestnut growth, and those that from their character and situation may, in consequence of being cleared or tilled, give rise to landslips, caving, or gullying, avalanches and snowslides, and may to the public injury interfere with water courses or change the character of the soil or injure local hygienic conditions. Government aid is to be extended where reforestation appeared necessary.

Of the 76,000 acres which required immediate reforestation, for reasons of public safety, only 22,000 were reforested in twenty years up to 1886, the Government contributing $85,000 toward the cost.

In the revised law of 1888, as a result of the vast experiences preceding, a further elaboration of the same plan was attempted by creating further authority to enforce action. It is now estimated that 534,000 acres need reforesting at a cost of $12,000,000, of which two-fifths is to be contributed by the State.

Expropriation proceedings may be instituted where owners refuse to reforest, with permission to reclaim in five years by paying the cost of work, with interest, incurred by the State.

In Austria, the disastrous consequences which the reckless devastation and abuse of her mountain forests by their owners has brought upon whole communities have led to a more stringent and general supervision of private and communal forests than anywhere else. Since 1883 there

has been also in progress a work of recuperation similar to the French reboisement work, in which, up to 1894, nearly $1,500,000 had been spent, the State contributing variously from 25 to 100 per cent toward covering the expense. A fully organized forest department manages the Government forests, 2,000,000 acres, which are gradually being increased by purchase, or 73 per cent of the whole forest area. One higher, and several lower schools provide instruction.

Some 150,000 acres of waste land were reforested by the State between 1881 and 1890.

Even Russia, although one of the export countries, with $30,000,000 to $35,000,000, and largely in the pioneering stage, has a well-devised forest policy, developed within the last thirty or fifty years, which consists not only in maintaining Government forests to the extent of about 280,000,000 acres under tolerably good management, and 30,000,000 of Crown forests, personal property of the royal family, but in restricting private owners from abuse of their property, where the public welfare demands, while in the prairie country in southern Russia large amounts of money are spent by the Government in planting forests and assisting private enterprise in the same direction.

With the Siberian forests and those of the Caucasus added, the area of Government forest may reach the large figure of 600,000,000 acres, which, though not yet all placed under management, is sooner or later to come under the existing forest administration.

The restrictive policy dates from a very elaborate law passed in 1888, in which the democratic spirit in the constitution of the body controlling the exercise of property rights is interesting. The approval of working plans or of clearings on private property is placed in the hands of a specially constituted committee for each county, which includes the governor, justices of the peace, the county council, and several forest owners, and the Government itself must secure the approval of this committee for its operations.

By this law, throughout European Russia, woodlands may be declared "preserved forests" on the following grounds: That they serve as preventives against the formation of barrens and shifting sands, and the encroachment of dunes along seashores or the banks of navigable rivers, canals, and artificial reservoirs; that they protect from sand drifts towns, villages, cultivated land, roads, and the like; that they protect the banks of navigable rivers and canals from landslides, overflows, or injuries by the breaking up or passing of ice; when growing on hills, steep places, or declines, they serve to check land or rock slides, avalanches, and sudden freshets, and all forests that protect the springs and sources of the rivers and their tributaries.

In these preserved forests, working plans are made at the expense of the Government, and in the unpreserved forests at the expense of the owners. In each province the Government maintains an inspector-instructor, whose duty is to advise those who apply to him in forest matters, and as far as possible he is to superintend on the spot all forestry work. The Government has established nurseries from which private owners can obtain young trees and seeds at a low price. The owners are allowed to employ as managers of their forests the trained officials of the forest administration, while medals and prizes are given yearly to private owners for excellency in forest culture and management. Two higher and thirteen lower schools of forestry are also maintained by the Government.

The country which has attracted most interest in all matters pertaining to forestry, because the science of forestry is there most developed and most closely applied, is Germany. The policies prevailing and methods employed are fully described in another part of this report.

It may, however, be interesting to trace somewhat the historical development both of the application of forestry principles and of the existing forest policy.

Although as early as Charlemagne's time a conception of the value of a forest as a piece of property was well recognized by that monarch himself, and crude prescriptions as to the proper use of the same are extant, a general really well-ordered system of forest management hardly existed until the beginning of the eighteenth century. Sporadically, to be sure, systematic care and regular methods of reproduction were employed even in the thirteenth and fourteenth centuries.

To understand the development of the present forest policy in Germany one must study the peculiar conditions and development of property rights that led to it. Germany was originally settled by warriors, who had to keep together in order to resist enemies and conquerors on every

side, ready to move and change domicile at any moment. The soil which was conquered, consequently, was not divided, but owned as a whole, managed by and for the whole tribe. It is only in the sixth century that signs of private property in woodlands are discernible. Before that time it was *res nullius*, or, as it is expressed in legal manuscripts, "*quia non res possessa sed de ligno agitur.*"

Wood being plentiful and yet needed by everybody, it appeared a crime only to take wood which had been already appropriated or bore unmistakable signs of ownership, such as being cut or shaped. But severe punishments were in earliest times inflicted for incendiarism and for damage to mast trees, since the seed mast for the fattening of swine was one of the most important uses of the forest.

There was not much need of partition, especially of the forests. The community, to which all the land of a district belonged, and which was managed by and for the aggregate of society, was called the "mark," a communistic institution of most express character, and every "marker" or shareholder was allowed to get the timber needed by him for his own use without control.

This early communal ownership of forest land undoubtedly explains the fact that even to-day over 5 per cent of the forest is owned by communities, cities, or villages. Gradually the necessity of regulating the cutting of the wood became apparent, as the best timber in the neighborhood of the villages was removed, and we find quite early mention of officials whose duty it was to superintend the felling, removing, and even the use of the timber. By and by even the firewood was designated by officials. Manufacturers received their material free of charge, but only as much as was needed to supply the community. Occasionally there were rules that each man had to plant trees in proportion to his consumption. So that by the end of the fourteenth century quite a system of forest management had been developed.

Meanwhile the Roman doctrine of the regal right to the chase had also begun to assert itself by the declaration of certain districts as ban forests or simply forests, in which the King exclusively reserved the right to chase. The Kings again invested their trusted followers and nobles with this right to the chase in various districts, thus gradually dividing the control of the same.

While at first these reservations did not bring with them restrictions in the use of the timber or pasture or other products of the forest, gradually these uses were construed as exercised only by permission, and the former owners were reduced to holders of "servitudes," i. e., holders of certain rights in the substance of the forests. The fact that the feudal lords frequently became the obermarkers or burgomasters of the mark community lent color of right to these restrictions in the use of the property, besides the assertion that the needs of maintaining the chase required and entitled them to such control.

It is interesting to note that through all the changes of centuries. these so-called servitudes have lasted until our own times, much changed, to be sure, in character, and extending by new grants especially to churches, charitable institutions, cities, villages, and colonists. Such rights, to satisfy certain requirements from the substance of an adjoining forest, were then usually attached to the ownership of certain farms, and involved counter service of some sort, usually in hauling wood or doing other forestry work.

Sometimes when the lordly owners of large properties exercised only certain prerogatives to show ownership, these, in the course of time, lapsed into the character of servitudes, the forest itself by occupation becoming the property of the community. With changes in value and other changes in economic conditions, these rights often became disadvantageous and more and more cumbersome to either or both sides.

The present century has been occupied with the difficult labor of relieving this state of things and making equitable arrangements by which the forests become unencumbered and the beneficiaries properly satisfied by cession of land or a money equivalent.

This chapter of the history of forest policy is especially interesting to us as a tendency, nay the practice exists of granting such rights to the public timber to the settlers in the Western States, which by and by will be just as difficult to eradicate when rational forest management is to be inaugurated.

Over 5,000,000 marks and several hundred acres of land were required in the little Kingdom of Saxony to get rid of the servitudes in the State forests. The Prussian budget contains still an

item of 1,000,000 marks annually for this purpose; and although over 22,000,000 marks and nearly 20,000 acres of land have been spent for this purpose in Bavaria, the State forests there are still most heavily burdened with servitudes.

The doctrine of the regal right to the chase, as we have seen, led to the gradual assertion of all property rights to the forest itself, or at least to the exclusive control of its use. This right found expression in a legion of forest ordinances in the fifteenth and sixteenth centuries, which aimed at the conservation and improvement of forest areas, abounding in detailed technical precepts.

At first treating the private interest with some consideration, they gradually more and more restrict free management. Prohibition of absolute clearing, or at least only with the permission of the government; the command to reforest cleared and waste places; to foster the young growth; limiting the quality of timber to be felled; preventing devastation by prohibiting the pasturing of cattle in the young growth, of the removal of the forest litter, of pitch gathering, etc., were among these prescriptions, and many others, such as prescribing the manner and time of felling, the division into regular felling lots, determination as to what is to be cut as firewood and what as building timber. Then, with the increasing fear of a reduction in supplies, followed prohibitions against exportation, against sale of woodlands to foreigners, against speculation in timber by providing schedules of prices, and from time to time entire exclusion from sale of some valuable species. Even the consumer was restricted and controlled in the manner of using wood.

In mediæval times, besides private forests of the King and lords, only the communal forest (allmende) was known, and small holdings of farmers were comparatively rare until the end of the Middle Ages.

The thirty years' war and the following troublesome times gave rise not only to extended forest devastation, but also to many changes in ownership of woodlands. With the growing instability of communal organization of the "mark," division of the common property took place, and thus private ownership by small farmers came about, reducing the communal holdings. Colonization schemes by holders of large estates also led to dismemberment.

A very large amount of the mark forest came into possesssion of the princes and noblemen by force, and later possessions of the princes were increased by the secularization of the property of monasteries and churches. Until the end of the last century these domains belonged to the family of the prince, just as the right to the throne or the governing of the little dukedom, contributing toward the expenses of government.

But when, as a consequence of the French Revolution and the Napoleonic wars and subsequent changes, the conception of the rights of the governing classes changed, and in some States like Prussia much earlier, a division of domains into those which belonged to the prince's family as private property and those which were State forests was effected, so that now the following classes of forest property may be distinguished:

(1) State forests, which are administered by the government for the benefit of the commonwealth, each State of the Confederation owning and administering its own.

(2) Imperial forests, belonging to and administered for the benefit of the Empire, situated in the newly acquired province of Alsace-Lorraine.

(3) Crown forests (Fidei-commiss), the ownership of which remains in the reigning family, administered by State government, but the revenues of which are in part applicable to government expenses.

(4) Princely domains, which are the exclusive and private property of the prince.

(5) Communal forests possessed by and administered by and for the benefit of village and city communities, or even provinces as a whole.

(6) Association forests, the owners of the old "mark" forests, possessed by a number of owners, the State sometimes being part owner.

(7) Institute and corporation, school or bequest forests, which belong to incorporated institutions, like churches, hospitals, and other charitable institutions.

(8) Private forests, of larger or smaller extent, the exclusive property of private owners.

The proportions of these classes of property which existed in the beginning of the century

experienced considerable changes by the sale of State forests, the sales being due partly to financial distress, partly to a mistaken application of Adam Smith's theories, which supposed that free competition would lead to a better management and highest development of the forest industry as well as of other industries.

This tendency, however, was checked when the fallacy of the theory became apparent, especially with reference to a property that demands conservative treatment and involves such time element as we have seen.

The hopes which were based on the success of individualistic efforts were not realized, and although control of private action had been retained by the State authorities, this could not always be exercised, and the necessity of strengthening the State forest administration became apparent. The present tendency, therefore, is not only to maintain the State forests, but to extend their area by purchase, mostly of devastated or deforested areas and by exchange for agricultural lands from the public domain. Thus, in Prussia, the increase of State forest area has been at the rate of 14,000 acres per year since 1867.

In districts where small farmers own extensive areas of barrens a consolidation is effected, the parcels of remaining forest and the barrens are put together, the State acquires these and pays the owners either in money or other property.

In Prussia, during the decade 1882–1891, 30,000 acres were in this way exchanged for 17,000 acres, and in addition some 200,000 acres, waste or poorly wooded, purchased at an expense of $3,500,000, round numbers. During the same decade the reforestation of 80,000 acres of waste lands was effected, while nearly 75,000 acres in the State's possession remained to be reforested.

The annual budget for these reforestations of waste lands has been $500,000 for several years.

The area of barrens and poor soils, only fit for forest purposes in Prussia, is estimated at over 6,000,000 acres.

The present distribution of the property classes for the whole Empire of the 35,000,000 acres of forest is about as follows, varying, to be sure, very considerably in the States of the Confederation:

	Per cent.
State and Crown forests (of which the Crown owns less than 2 per cent)	32.7
Imperial forests	1
Communal forests (5,000,000 acres)	15.2
Association forests	2.5
Institute forests	1.3
Private forests	48.3

The State and Crown forests are all under well-organized forest administrations, sometimes accredited to the minister of finance, sometimes to the minister of agriculture. These yield an annual net revenue of from $1 to $5 and $6 per acre of forest area, with a constant increase from year to year, which will presently be very greatly advanced when the expenditures for road building and other improvements cease.

In the State management the constant care is not to sacrifice the economic significance of the forest to the financial benefits that can be derived, and the amount cut is most conservative.

The Imperial forests are of course managed in the same spirit as the several State forests.

While the present communities, villages, towns, and cities are only political corporations, they still retain in some cases in part the character of the "mark," which was based upon the holding of property.

The supervision which the princes exercised in their capacity of Obermarker or as possessor of the right to the chase, remained, although based on other principles, as a function of the State when the "mark" communities collapsed, the principles being that the State was bound to protect the interest of the eternal juristical person of the community against the present trustees, that it had to guard against conflicts between the interest of the individual and that of the community in this property, and secure permanency of a piece of property which insured a continued and increasing revenue. The principle upon which the control of these communal holdings rests is then mainly a fiscal one.

The degree of control and restriction varies in different localities. Sale and partition and

clearing can mostly take place only by permission of the State authorities, and is usually discountenanced except for good reasons (too much woods on agricultural soil).

With reference to 5.6 per cent of communal forest property, this is the only control which is of a fiscal nature. The rest is more or less closely influenced in the character of its management, either by control of its technicalities or else by direct management and administration on the part of the Government.

Technical control makes it necessary that the plans of management be submitted to the Government for sanction, and that proper officers or managers be employed who are inspected by Government foresters. This is the most general system, under which 49.4 per cent of communal forests are managed (as well in Austria and Switzerland), giving greatest latitude and yet securing conservative management. To facilitate the management of smaller areas several properties may be combined under one manager, or else a neighboring government or private forest manager may be employed to look after the technical management.

Where direct management by the State exists, the State performs the management by its own agents with only advisory power of the communal authorities, a system under which 45 per cent of the communal forests are managed (also in Austria and France).

In Prussia this system exists only in a few localities, but it is since 1876 provided as penalty for improper management or attempts to avoid the State control.

This system curtails, to be sure, communal liberty and possibly financial results to some extent, but it has proved itself the most satisfactory from the standpoint of conservative forest management and in the interest of present and future welfare of the communities. Its extension is planned both in Prussia and Bavaria.

Sometimes the State contributes toward the cost of the management on the ground that it is carried on in the interests of the whole commonwealth. A voluntary cooperation of the communities with the State in regard to forest protection by the State forest guards is in vogue in Wurttemberg, and also in France. Institute forests are usually under similar control as the communities.

The control of private forests is extremely varying. A direct State control of some kind is exercised over only 29.7 per cent of the private forest, or 14.6 per cent of the total area, mostly in southern and middle Germany, while 70.3 per cent of the private property, or 34.5 per cent of the total forest area, is entirely without control, a condition existing in Prussia and Saxony.

As far as the large land owners are concerned, this has mostly been of no detriment, as they are usually taking advantage of rational management; but the small peasant holdings show the bad effects of this liberty quite frequently in the devastated condition of the woods and waste places. As a recent writer puts it: "The freedom of private forest ownership has in Prussia led not only to forest dismemberment and devastation, but often to change of forest into field. On good soils the result is something permanently better; on medium and poor soils the result has been that agriculture, after the fertility stored up by the forest has been exhausted, has become unprofitable. These soils are now utterly ruined and must be reforested as waste lands.

Need, avarice, speculation, and penury were developed into forest destruction when in the beginning of this century the individualistic theories led to an abandonment of the control hitherto existing, and it was found out that the principle so salutary in agriculture and other industries was a fateful error in forestry.

Where control of private forests exists it takes various forms:

(1) Prohibition to clear permanently or at least necessity to ask permission exists in Wurttemberg, Baden, and partially in Bavaria. (Protection of adjoiners.)

(2) Enforced reforestation within a given time after removal of the old growth and occasionally on open ground where public safety requires.

(3) Prohibition of devastation or deterioration—a vague and undefinable provision.

(4) Definite prescription as to the manner of cutting (especially on sand dunes, river courses, etc.).

(5) Enforced employment of qualified personnel.

In addition to all these measures of restriction, control and police, and enforcement, there

should be mentioned the measures of encouragement, which consist in the opportunity for the education of foresters, dissemination of information, and financial aid.

In the latter respect Prussia, in the decade 1882–1892, contributed for reforestation of waste places by private owners $335,000, besides large amounts of seeds and plants from its State nurseries. Instruction in forestry to farmers is given at twelve agricultural schools in Prussia. In nearly all States permission is given to Government officers for compensation, to undertake at the request of the owners the regulation or even management of private forest property.

For the education of the lower class of foresters there may be some twenty special schools in Germany and Austria, while for the higher classes not only ten special forest academies are available, but three universities and two polytechnic institutes have forestry faculties.

Besides, all States have lately inaugurated systems of forest experiment stations; and forestry associations, not of propagandists but of practitioners, abound. As a result of all this activity in forestry science and practice, not less than twenty forestry journals in the German language exist, besides many official and association reports and a most prolific book literature.

E. FOREST CONDITIONS AND METHODS OF FOREST MANAGEMENT IN GERMANY, WITH A BRIEF ACCOUNT OF FOREST MANAGEMENT IN BRITISH INDIA.

Forest Area, Extent and Ownership.

Germany, as constituted at present, has an area of 133,000,000 acres—about one-fifteenth of our country—a population of about 47,000,000, or less than 3 acres per capita, or only one-tenth of our per capita average. Its forests cover 34,700,000 acres, or 26 per cent of the entire land surface. A large portion of the forests cover the poorer, chiefly sandy, soils of the North German plains, or occupy the rough, hilly, and steeper mountain lands of the numerous smaller mountain systems, and a small portion of the northern slopes of the Alps. They are distributed rather evenly over the entire Empire. Prussia, with 66 per cent of the entire land area, possesses 23.5 per cent of forest land, while the rest of the larger States have each over 30 per cent, except small, industrious Saxony, which lies intermediate, with 27 per cent of forest cover.

Considering the smaller districts of Prussia, Bavaria, and the smaller States, it is found that out of 64 provinces and districts, 18 have less than 20 per cent forest; 18 have from 20 to 29 per cent; 23, including the greater part of the country, have from 30 to 39 per cent, and 5 of the smaller districts have from 40 to 44 per cent of forest. The districts containing less than 20 per cent of forests are, as might be supposed, mostly fertile farming districts in which the plow land forms over 40 per cent of the land, but they also include neglected districts like Hanover and Luneburg, where a former shortsighted, selfish, and improvident policy has led to the deforestation of poor, flat lands, which have gradually been transformed into heaths, where an accumulation of bog-iron ore, and other obstacles render the attempts at reforestation difficult, expensive, and unsatisfactory. Left to forests, these same lands, which now are unable to furnish support to farmers or to produce a revenue to their owner, could easily pay the taxes and interest on a capital of $50 to $100 per acre. To reforest them now costs $10 to $50 per acre and requires a lifetime before any returns can be expected.

Since it is one of the common claims in the eastern United States that the land is all needed for agriculture, and since it will be conceded that in hardly any State east of the Mississippi much land necessarily remains untilled, it may be of interest to note that in this densely populated Empire of Germany out of 67 districts and provinces the plow land forms less than 20 per cent in 4 districts, 30 to 39 per cent in 10 districts, 40 to 49 per cent in 26 districts, 50 to 59 per cent in 20 districts, and 60 to 69 per cent in 7 districts, in spite of the fact that a large part of the forests are in private hands and would be cleared if the owners saw fit to do so.

In our country the total area in farms is only 18 per cent at present.

Of the total of 34,700,000 acres of forest land (an area about as large as the State of Wisconsin) 32.7 per cent belongs to the several States as State property; 19 per cent belongs to villages, towns, and other corporations, and 50 per cent to private owners, a considerable part of this being in large estates of the nobility.

The following figures show these ownership relations for the eight larger States, which involve 96 per cent of the total area of the empire:

State.	Population.	Total land surface.	Forests.				
			Total.	Per cent.	Owned by the— State.	Corporations.	Private.
	Millions.	*M acres.*	*M acres.*		*M acres.*	*M acres.*	*M acres.*
Germany	47	133,392	34,750	100	11,360	6,710	16,680
Prussia	29.9	88,000	20,240	58	6,100	3,240	10,900
Bavaria	5.6	18,800	6,200	18	2,160	890	3,150
Wurttemberg	1.9	4,800	1,470	4.2	480	470	530
Saxony	3.2	3,700	1,020	3	430	60	530
Baden	1.6	3,730	1,360	4	237	667	447
Alsace-Lorraine	1.5	3,600	1,100	3.1	360	520	220
Hesse	.9	1,900	590	1.7	170	220	200
Mecklenburg-Schwerin	.5	3,290	560	1.6	255	85	220

This same relation, expressed in per cent, becomes:

State.	Forest cover of total area.	Forests owned by— States.	Corporations.	Private.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Germany	25.7	32.7	19	48.3
Prussia	23.5	30	17	53
Bavaria	35	34	14	52
Wurttemberg	31	32	32	36
Saxony	27	43	6	51
Baden	37	18	49	33
Alsace Lorraine	30	33	47	20
Hesse	31	29	37	34
Mecklenburg-Schwerin	17	46	15	39

The condition of the forests to a great extent depends on the degree of supervision or control exercised by the State authorities. It is best in all cases in the State forests, is equally good in the corporation forests under State control, and is poorest in the private forests, particularly those of small holders.

STATE CONTROL.

The amount of State influence or control varies in the several States, and varies in some cases even in one and the same State for different districts. Of the State forests, without exception, it can be said that they are nearly in that form which, according to present knowledge and with reasonable effort, is able to produce the greatest quantities of wood material in those dimensions and of such kinds as best to satisfy the demands of the markets and at the same time render the management as profitable as possible. This does not mean that they are not improving, for as forestry knowledge increases and the methods are perfected the results are better. From what follows it also appears that all State forests as a whole pay, and pay handsomely, when the low intrinsic value of the land on which the forest stocks is considered.

The control of the corporation forests is perfect only in a few of the smaller States, notably Baden, Hesse, and Alsace-Lorraine; also in some districts in Prussia where the corporation forests are managed by the State authorities, the wishes of the villagers or corporate owners being, however, always duly considered. In a large portion of Prussia, in Wurttemberg, and in Bavaria the corporation provides its own foresters; but these must be approved, as well as their plans of operations, by the State authorities, so that here the management is under strict control of the State, and favorable forest conditions at least partially assured. In Wurttemberg the corporation is given the choice of supplying its own foresters or else joining their forests to those of the State. This has led to State management of near 70 per cent of all corporation forests. Only the corporation forests of Saxony and those of a small part of Prussia are without any supervision. Of the private forests, those of Prussia and Saxony, involving 69 per cent of all private forests of the Empire, are entirely free from interference. They can be managed as the owner sees fit, and there is no obstacle to their devastation or entire clearing and conversion into field or pasture. The remainder of the private forests are under more or less supervision. In most districts a State permit is required before

land can be cleared. Devastation is an offense, and in some States, notably Wurttemberg, a badly neglected forest property may be reforested and managed by State authorities. In nearly all States laws exist with regard to so-called "protective forests" i. e., forests needed to prevent floods, sand blowing, land and snow slides, or to insure regularity of water supply, etc. Forests proved to fall under this category are under special control, but as it is not easy in most cases to prove the protective importance of a forest, the laws are difficult to apply and rarely enforced.

A partial return to the State supervision of private forests has been attempted in Prussia by the establishment of a law which renders the owner of a forest liable for the damage which the devastation or clearing of his forest property causes to his neighbor. This law, however, like the former, is so difficult to apply, and puts the plaintiff to great expense, so that so far it has not been enforced to any extent except where the Government itself is the injured party.

In the following statement the areas of forest are grouped according to the degree of State supervision and manner of management:

Of the entire 34,700,000 acres of forest land, there are approximately—

(1) Managed by State authorities as State property, 11,360,000 acres, which is 32.7 per cent.

(2) Managed by the State authorities, but the property of corporations, villages, towns, etc., a little over 2,212,000 acres, which is 6.3 per cent.

(3) Under strict Government control, the plans of management and the permissible cut having to be approved by State authorities (corporation property), 3,875,000 acres, which is 11.1 per cent.

(4) Under supervision of the State, not only as common property but as special property, subject to inspection and, in part, to control of State forest authorities; nearly all private property and partly belonging to large estates, 4,767,000 acres, which is 13.7 per cent.

(5) Without any Government control or supervision beyond that of common property. These forests may be divided, sold, cleared, and mismanaged, except under the certain cases before mentioned. Here belong all private forests of Saxony and Prussia and part of the corporation forests of Prussia and all those of Saxony, 11,490,000 acres, which is 33 per cent.

CHARACTER OF FOREST GROWTH.

The greater part of the German forests is stocked with conifers, chiefly pine (the Scotch pine, a pine similar to our red or Norway pine) and spruce. The pine prevails on the sandy areas of North Germany, and occupies about 60 per cent of the Prussian and 30 per cent of the Bavarian forests. The spruce is the chief conifer and principal timber tree of Saxony and southern Germany. The hard woods, chiefly beech, some oaks, with small amounts of ash, maple, elm, etc., are most abundant in the valley of the Rhine, Lorraine, and Wurttemberg, but good beech forests occur in nearly all parts of the Empire.

The greater part of all forests of Germany are "timber forests," where the trees are cut at an age of over 80 years (generally 90 to 120 years).[1] Timber forests form over 90 per cent of the State forests of all larger States, are the prevalent form in the forests of corporations, and are common in those of private owners. The other two common forms, the "coppice" and "standard coppice," where the trees are cut at an age of less than 30 years (usually 15 to 25 years, and in the standard coppice a small part only is allowed to reach better age and size), are most abundant in private forests and to a less extent in corporation properties, but form only a very small part of the State woods, where they are steadily diminishing in importance. The coppice is a hard-wood forest, depends on the sprouting capacity of the trees, and furnishes small poles, firewood, and tanbark. Both forms of the coppice and standard coppice require a smaller amount of standing timber, furnish quicker returns, but do not furnish those kinds of products which the market demands in largest quantity.

In the timber forest the trees of any particular tract or division are supposed to be of about the same age, differing not over 20 years in the extreme, so that for a rotation of one hundred years, i. e., a management where the crop is harvested at the age of 100 years, one-fifth, or 20 per cent, of all the forests should be 1 to 20 years old; another 20 per cent, 21 to 40 years old, etc. In spite of the great difficulty of attaining this regularity of distribution in the forests of an entire State without disturbing the yearly cut of timber, this regularity is already attained very closely in most of the State forests. Thus in the State forests of Prussia, of the total area of

[1] For fuller description of the systems of management, see pp. 225 to 259 of this report.

timber forest (90 per cent of all State forests), the age of the timber is as follows: On 13 per cent of the area, over 100 years old; on 13 per cent, 81 to 100 years old; on 14 per cent, 61 to 80 years old; on 18 per cent, 41 to 60 years old; on 19 per cent, 21 to 40 years old; on 19 per cent, 1 to 20 years old, and about 4 per cent are clearings, where the timber has been cut lately. In all forests the ground is at once reforested, if cut clean, or else the cut is so arranged that a natural seeding goes on as the harvest progresses, this latter consisting of several fellings, separated by a number of years.

EXPLOITATION.

The cutting in all State forests is generally done by the cord or by the cubic foot (really by the stere, festmeter, or cubic meter). In rare cases the timber is cut and moved by the purchaser; nearly always it is cut and moved by the forest authorities and sold and delivered at the main roads. The logs are not cut to uniform lengths, but care is had in the forest to cut to best advantage. Long, straight timbers are left long, if possible, and sold as long, round, or sometimes hewn pieces; saw timber is cut in even lengths; poles are cut to suit local markets; wagon and coopers' stock, etc., are cut to suit, or left in round timbers, while pulp wood, cord wood, and branches, and sometimes even stumps, are worked up in customary manner, graded, and sold by the cord (really "stere" or "raummeter").

In the conversion of the logs into lumber there are more complications in dimensions than with us. The measure is generally the meter and centimeter; edging is not done by even numbers. Lumber is sold by cubic measure, and the handling is thus generally not so simple as in America.

As far as practical means and methods in felling and logging operations go we can learn but little from Germany, except that more care in the utilization of the timber would be profitable here as it is abroad. Yet it may be of interest, and not entirely devoid of suggestive value, to briefly recite the practices followed in most Government forests.

The location of fellings for the year having been determined with due consideration, the rangers engage and control, under supervision of the district manager, the crew of wood choppers under a foreman, who are mostly men living in the neighborhood of the range or district and accustomed to all kinds of forest work.[1] A contract, which contains conditions, regulations, and a scale of prices, is made with them, which they sign. The men are paid by the job, the prices per unit differing, of course, in different localities and being graded according to the kinds of timber, size, etc.

To cite one example we may take the schedule prices paid at the forest belonging to the city of Goslar, as this will interest us further on. There are 40 men nearly permanently employed either in wood chopping, planting, or otherwise, and their average earnings during three years have been about 80 cents per working day. The prices for cutting spruce, including moving to roads and barking, and the average prices obtained for ten years were as follows:

Cost of cutting.	Average price obtained in the woods.	
	Lowest class.	Highest class.
Saw timber, above 5 inches in diameter (5 classes), 85 cents per 100 cubic feet.	$9.50	$16.20
Long poles (3 classes), from 84 cents to $1.68 per 100 cubic feet	5.90	7.90
Small poles (4 classes), from $1.37 to $3.07 per 100 cubic feet	3.60	5.80
Firewood, split, 70 cents to $1 per cord	3.60	4.30
Firewood, brush, $1.10 per cord	....	1.60

In Prussia the average cost of lumbering (wood cutting and bringing to roads) for all kinds and dimensions is 65 cents per 100 cubic feet; that is to say, the wood-choppers' bill on the 300,000,000 solid cubic feet of wood harvested annually in the Prussian Government forests amounts to $1,950,000. It will appear from the prices for wood cited that often the harvesting is more expensive than the price obtained, as, for instance, for brushwood, which will hardly sell for half the cost of cutting, but its removal is necessary from cultural considerations. The wood choppers are also sometimes expected to move the cordwood at least to the neighboring roads, so as to obviate the driving of teams through the woods or young growth.

[1] In the census of Germany for 1881–82 there were reported as engaged in forestry, hunting, and fishing 384,637 persons. Unfortunately, no division of the three occupations was made.

If the felling is to be a clearing, a strip is assigned to each gang of 3 men, 1 with an ax and 2 with saws (felling with the saw, of course, is the rule); if a regeneration cutting or thinning, the trees to be taken are carefully selected by the ranger or manager and marked with a marking hammer. As a rule, all fellings are done during winter, and all trees, except in the coppice and small poles, are felled with the saw close to the ground. In the pineries of the North German plain, where the root wood is salable, they are even dug out and then sawed off close to the root, thus saving a good piece of log timber, which in Saxony increases the wood value of the harvest by fully 3 per cent. Which parts of the log are to be cut into firewood and which into lumber wood or special timbers, and the length of the same according to the best use that can be made of the stick, are determined by the foreman, or in valuable timber by the ranger or manager himself. A scale of sizes and classes of timber (sortiment) exists; in general, all wood over 3 inches diameter is called Derbholz (coarse wood or lumber wood), all below 3 inches is brushwood (Reisholz), with which root wood (Stockholz) is classed. These last two grades are used as firewood, with which is also classed body wood or split wood (Scheitholz), split from pieces over 6 inches diameter at the small end, and round billet wood (Knüppelholz) of 3 to 6 inches diameter.

The wood to be used in the arts, called timber wood (Nutzholz), may appear either in bolts, corded, or in logs. The diameter measurement of logs is made by the ranger, with calipers, at the middle of the log. Every cord and every log is numbered and the diameter and length noted on the log, and a list prepared in which the cubic contents are calculated. From this list the manager checks off the result of the felling, marking each piece or cord with the marking hammer, and after advertisement sells at public auction, in the woods or at some public place, the single pieces or cords to the highest bidder over and above the Government rate, which for the different grades is established every three years on the basis of, but below current market prices. The sale of logs is made per cubic foot, and the size of the log influences the rate or price, heavier logs being disproportionately higher in price.

PRICE OF WOOD IN THE FOREST.

During the years 1884–1887 the following prices were obtained by the Prussian forest administration for wood in the forest. This is practically for stumpage, cut and marked, the buyer hauling it from the woods:

Price per 100 cubic feet of wood in Prussia.

Pieces containing 18–36 cubic feet.	Lowest price.	Highest price.	Average price.
Timber:			
Oak	$8.50	$17.30	$12.00–14.00
Beech, ash, elm, maple	5.50	12.25	7.50– 8.50
Spruce	4.75	11.65	7.00– 8.00
Pine	4.75	11.00	6.25– 6.35
Firewood:			
Beech, ash, elm, maple	.75	1.75	1.00– 1.20
Spruce	.40	1.50	.70– .85
Pine	.45	1.30	.80– .90

To gain an idea of the appreciation of the wood product, without reference to kind, size, and quality, the following series of figures will serve:

Average price per 100 cubic feet of wood realized by the Prussian Government for its entire crop (about 300,000,000 cubic feet).

Year.	Price.
1850	$3.27
1855	3.66
1860	3.69
1865	4.71
1870	4.35
1875	5.21
1880	4.47
1885	4.30
1890	4.40

The highest price for any district was obtained in 1888, being $8.49, while the lowest was $2.82. The lower prices in later years are explained by the large importations of wood, especially from Hungary, Russia, and Sweden; for while our misinformed forestry friends point to Germany as the Eldorado of forestry and proclaim the proportion of forest area there maintained, namely,

about 25 per cent, as the ideal and necessary for self-support, and therefore to be maintained also in this country, they overlook the fact that Germany imports not less than $60,000,000 worth of wood and wood manufactures, mostly of the same kind as grown or manufactured in that country. This represents about 10 per cent of the total consumption of Germany, while the importations of the United States, which imports from Canada only competing classes of forest products, represent not more than 1 per cent of our probable consumption.

The exports of forest products from Germany, on the other hand, are, to be sure, nearly 50 per cent of her imports, but they represent mostly manufactures, while in the United States the reverse is the case; that is to say, the United States exports twice as much as it imports, and that mostly raw material, namely, twice as much in value of raw material as of manufactures.

The countries from which Germany imports raw or partly manufactured wood are mainly Russia, Austria-Hungary, and Sweden, which furnish nearly five-sixths of the total importation, while Holland, England, Denmark, Belgium, France, and Switzerland draw about $14,000,000 worth of raw material from Germany. (See tables further on.)

To protect the forest owners of Germany, a tariff on importations was imposed in 1885 and increased later. Of the effects of this last measure a government report says that as a financial measure these tariffs have had excellent success, for the revenue from these duties increased from $646,000 in 1880 to $1,732,000 in 1886. But for the forest owner the hoped-for results did not become apparent; the Austro-Hungarian railroads and shipping interests lowered their rates so as to largely equalize the duty charges. The duties on unmanufactured materials being very low, the lack of results in the market of these is still more noticeable. Yet a salutary effect is stated to be a prevention of still lower prices, and because otherwise there would have been a lack of useful occupation for labor finding remunerative employment in the manufacture of the raw material, which, without the increase in duties, would have been imported in manufactured condition.

PRICE OF MANUFACTURED LUMBER.

The following samples of schedules for manufactured lumber, always delivered at the railroad station, may serve to give an idea to our lumbermen how nearly prices compare with those prevalent in our country. We choose those of eastern provinces, which are in sharpest competition with Russian and Hungarian imports:

Province of Posen.

Timber (7–8.5 inch square):			
Pine	per cubic foot	$0.20 to	$0.22
Spruce	do		.16
Pine (Scotch):			
Plank (2–4 inch), 3 classes	per 1,000 feet B. M.	27.00	38.00
Plank (1½–1¾ inch), 3 classes	do	26.00	31.00
Flooring (1-inch), 3 classes	do	17.00	22.00
Flooring (1½-inch), 3 classes	do	20.00	26.00
Spruce, rough boards, not edged (4–5 inch)	do		12.00
Spruce (1½-inch), edged, 12–18 feet	do	20.00	22.00

Delivered at Berlin.

Oak (clear), 82 cents per cubic foot, or $68 per 1,000 feet B. M.
Elm, 78 cents per cubic foot.
Railroad ties—pine, 45 cents; oak, 90–95 cents.

It will be seen that prices for some grades are as high as and higher than in New York. The manager is expected to secure at least the government rate, and has discretion in conducting the sales to the best advantage of the government. Under certain circumstances sales by contract without auctioneering, and, lately, selling on the stump, are permitted.

The transportation from the woods, as stated before, is usually left to the buyer; rarely does the administration float the timber or cord wood out, or carry it to a depot or wood yard to be sold from there, or engage in milling or other operations. On the other hand, it has been recognized during the last twenty-five years that good roads and other ready means of transportation increase the price of the wood disproportionately. A good road system is, therefore, considered the most necessary equipment of the administration, and an extension of permanent and movable logging railroads is one of the directions of modern improvement. The interesting, important, and practical features to us in the logging railroads are their movable character, being divided into

sets of pairs of short (2 to 5 yard) rails (12 to 16 pounds per yard) attached to from two to four cross-ties, wood or metal, the light sets weighing 75 to 100 pounds (heavy sets up to 166 pounds), so that one workman can readily carry them; the ready connection of sets, one hooking at once into the other without separate mechanism, forming a sufficiently satisfactory joint; the simple "climbing switch," which is applied on top of the track, permitting ready transfer from side track to main track and ready relocation. These roads can be readily laid down without much or any substructure and readily relocated. The cost is shown in the following statement:

For a fully equipped road, 24 to 28 inches width, 6 miles length, for rails and ties	$9,000
For earthwork, if any, and laying	50 to 500
For rolling stock and apparatus	2,500
	12,000

Or $2,000 per mile at the highest.

Upon a basis of 800,000 cubic feet (about 7,000,000 feet B. M.) to be transported, it is calculated that the cost of transportation by railroad, stone road, and dirt road will be about as 1:2:6, the cost on the first being about 3 cents per 1,000 feet B. M. per mile as against 18 cents on dirt roads.

Comparing the cost of construction it is stated that the ratio between corduroy, gravel road (13 feet wide), macadam, and movable track is as 1 : 1.25 : 2.35 : 1.17, placing the last among the cheapest.

A most instructive exhibit at the World's Fair, in many ways, especially at the present time, since the movement for better roads in this country has begun, was the model of the city forest of Goslar, a small town (13,300 inhabitants) in the Harz Mountains, whose citizens, from this piece of property, a spruce forest of 7,368 acres extent, derive not only their pure drinking water, healthful enjoyment in hunting, and refreshing coolness in summer, but also a net income, amounting in round numbers to $25,000 ($3.40 per acre), toward payment of city taxes. This is the result of careful management, which permits an annual cut of 350,000 cubic feet of wood. Of this only 50,000 cubic feet goes into firewood, and 46 per cent, or 160,000 cubic feet, is saw timber, which sells at 10 to 16 cents per cubic foot; while smaller dimensions, poles, etc., sell all the way down to below 4 cents, and firewood at $1.60 for brush to $4.30 for split or round wood per cord. Until 1875 the district was without proper roads. By an effort of the competent manager the city fathers were persuaded to locate and build a rational system of roads on which altogether, until 1891, there was spent for building and maintenance about $25,000. The greatest interest attaches to the statistics carefully gathered by the district manager, Mr. Reuss, since it is always difficult to determine the money value of such an expenditure in dollars and cents.

The proper location of the roads is the most important feature. The roads are ranked according to their importance; the width and manner of finish depend on their rank. Main roads are macadamized; roads of third rank, which are used for occasional hauling of wood, are dirt roads.

These statistics were exhibited in a neat table, as follows:

STATISTICS OF ROAD SYSTEM IN FOREST DISTRICT OF CITY OF GOSLAR (HARZ MOUNTAINS, GERMANY).

Properly located, graded, and built roads reduce cost of logging and hauling, and advance the price for wood. Area, 7,368 acres spruce forest; annual cut, 350,000 cubic feet; road building begun in 1875; total mileage of improved roads in 1891, 141 miles; cost of road system and maintenance until 1891, $25,000.

Cost of logging reduced by good logging roads.

[Daily wages remaining constant at 60 cents.]

Year.	Length of well-built logging roads.	Cost of logging per 100 cubic feet.
	Miles.	
1877	7.5	$1.93
1878	12	1.61
1879	27	1.54
1880	37	1.45
1881	46	1.15
1882	50	1.23
1883	52	1.15
1884	54	1.23

Saving per 100 cubic feet	$0.70
Saving on annual cost of 350,000 cubic feet	2,450.00

Cost of haulage reduced by good wagon roads.

[Price per load remaining constant at $3.60. Full load, before improvement, 85-100 cubic feet; after improvement, 175-250 cubic feet.]

Year.	Cost of haulage per 100 cubic feet.
1871-1877, before road improvements	$1.52
1878-1884	.98
1885-1891	.80

Saving per 100 cubic feet $0.72.00
Saving on annual cut of 350,000 cubic feet 2,520.00

Price of wood influenced by road improvements.

[Comparison of prices paid at Goslar and at other Harz districts.]

Year.	Length of improved wagon roads.	Prices for wood per 100 cubic feet.		
		At Goslar.	At other Harz districts.	Difference in favor of Goslar.
	Miles.			
1877	22	$8.25	$8.18	$0.07
1878	34	8.65	8.04	.61
1879	42	9.59	8.44	1.15
1880	55	9.79	8.44	1.35
1881	64	9.05	7.78	1.27
1882	68	8.45	7.43	1.02
1883	71	8.65	7.63	1.02
1884	77	10.17	8.18	1.99
1885	78	8.88	8.24	.64
1886	79	9.59	9.39	.20
1887	81	11.12	9.71	1.41
1888	82	11.12	9.98	1.14
1889	83	11.39	10.58	.81
1890	85	11.72	10.92	.82
1891	87	13.13	11.80	1.33
Average for fifteen years	....	9.91	8.98	.93

Increase in price on total cut of 350,000 cubic feet $3,255
Total profit from improved road system in reduced cost of logging and hauling, and in advance of price received for wood, per annum. 8,225

Or nearly 33 per cent on investment.

Saving their cost in two years.

Cost of road, macadamized in 1885, $6,960; maintenance for one year, $480; total, $7,440. During 1885-86 hauling 470,000 cubic feet requiring on old road 4,273 loads of 110 cubic feet average, at $3.60, $15,282.80 (or $2.70 per 1,000 feet B. M.); on improved road, 2,652 loads of 177 cubic feet average, at $3.60, $9,547.20 (or $1.70 per 1,000 feet B. M.), saving of $1 for every 1,000 feet B. M. Total saving in haulage, $5,735.60, or 77 per cent on cost of road in one year.

YIELD PER ACRE.

The amount of timber cut per acre is very large as compared with average yields in wild woods. Of late the average yield has varied from about 5,500 cubic feet per acre in Prussia to 9,000 cubic feet for the Saxon State forests. The yield has been steadily increasing since the beginning of this century, and in most States it has been nearly doubled through better management. At that earlier time much land was badly stocked or devoid of any cover, much timber was injured and stunted by continual removal of the litter and consequent impoverishment of the soil, and in most forests the young timber occupied much more than its share of ground, and thus less timber grew. In every one of the States and districts these conditions have been changed materially for the better, the cut was increased from year to year, the wood capital or standing timber grew in total amount, and the productive capacity of the forest soils has generally improved. The cut for any given province or State is generally given as so much per acre of total area. Thus the cut for Saxony is placed at 90 cubic feet per acre of total forest area, though, of course, the yield of those tracts actually cut was about 9,000 cubic feet per acre cut. In the following table the figures relating to the State forests are from recent official records, also those of the corporation forests of Baden, Alsace-Lorraine, Bavaria, and parts of Wurttemberg, while the figures for private forests and most of the corporation forests are estimates based on the experience of former years and of only part of the provinces.

Yearly cut per acre in the State and other forests of Germany (in million cubic feet.)

State.	Cut per acre of forested area.		
	Total (including stump and branch wood where used).	Wood over 3 inches (no stump wood).	Timber and bolt-size material (not firewood).
For the entire Empire	55	37.5	16.4
State forests of—			
Prussia	54	42	19
Bavaria	72	55	24
Wurttemberg	81	67	36
Saxony	90	68	54
Baden	74	59	24
Alsace-Lorraine	57	46	22
Hesse	75	52	16
Mecklenburg-Schwerin	61	50	11.6
The entire Empire	63	43	22.5
Corporation forests of the entire Empire *a*	56	41	16.6
Private forests of the entire Empire *b*	50	30	12

a Partly from official records, part estimate.
b Generally estimated, as no accurate data are available for any entire State.

Using the above basis, the total annual cut of the country (in million cubic feet) is about as follows:

State.	Total cut.	In the forests belonging to—		
		States.	Corporations.	Individuals.
Entire Empire	1,910	710	370	830
Prussia	1,054	331	178	545
Bavaria	354.5	153	44.5	157
Wurttemberg	89.5	38	25	26.5
Saxony	67.3	37.5	3.3	26.5
Baden	85.9	16.6	47	22.3
Alsace-Lorraine	65.3	21.3	33	11
Hesse	34.8	12.7	12.1	10
Mecklenburg-Schwerin	30.7	15	4.7	11

CONSUMPTION OF WOOD MATERIALS.

Thus Germany has a steady and increasing supply of over 1,900 million cubic feet of timber per year (about one-tenth of our consumption) from the lands which in most other countries remain barren wastes. Of these 1,900,000,000 there are near 600,000,000 cubic feet of saw timber and the like, the rest being cord wood and mostiy firewood. From this it would appear that Germany produces about 40 cubic feet of wood per head of population, and that of this about 12 cubic feet are saw timber, etc., as against 350 and 50 cubic feet for our consumption. But in spite of the great economy of wood this amonnt of home-raised material does not satisfy the demand of the home markets, and Germany with its 1,900,000,000 cubic feet is to-day the second greatest importer of wood, particularly of saw timber, in the world.

The import in this case means the excess of import over export, since naturally in all countries an export of some timber takes place.

Consumption of wood (million cubic feet).

Country.	Total.	Produced at home.	Imported.	Log timber, etc.		Per cent imported.	Relative importance as importers.
				Produced at home.	Imported.		
Germany	2,090	1,910	180	570	180	24	40
England	591	140	451	42	451	99	100
France	1,175	1,075	100	200	100	33	22

Per head of population, and comparing with the consumption in the United States, this becomes:

Consumption of wood per capita of population (cubic feet).

Country.	Total.	Produced at home.	Import over export.	Log timber.	Relative wood consumption per head.
					Per cent.
Germany	44	40.5	3.8	15	12.7
England	15	3.6	11.5	13	4.3
France	32	30	2	8.3	9
United States	350	349.7	0.3	*a* 50	100

a This refers to lumber or sawed material alone.

Since the consumption by sawmills of large timber, particularly coniferous material, is still increasing, it is clear that Germany has not nearly as much forest land as it needs, or else must still improve greatly its methods of production. At present 26 per cent of its saw timber, etc., is imported.

The following figures give an idea of the extent and distribution of the German trade in woods and wood manufactures:

Germany's trade in wood and wood manufactures, 1892.

Country.	Imports.	Exports.
United States	*a* $2,418,000	$1,504,000
Russia	*b* 26,908,000	741,000
Austria-Hungary	*c* 16,363,000	1,946,000
Sweden	*d* 5,222,000	305,000
France	1,796,000	3,405,000
England	1,313,000	13,449,000
Holland	822,000	2,546,000
Norway	849,000	176,000
Belgium	730,000	1,469,000
Denmark	56,000	967,000
Hamburg	124,000	1,551,000
Switzerland	220,000	1,822,000
East India	*e* 1,114,000	174,000
Spain	*f* 1,302,000	354,000
Argentina	*g* 359,000	129,000
Brazil	68,000	384,000
Porto Rico and Cuba	*h* 352,000	
Total	60,016,000	30,922,000

a Lumber. *b* Pine logs. *c* Oak, etc., logs. *d* Sawed lumber. *e* Largely rattan. *f* Nearly all cork. *g* Largely quebracho. *h* Mahogany, etc.

The prices paid by Germany have so far been very reasonable. Thus her imported lumber cost in 1892 only $18.30 per thousand feet; firewood only $6.50 per cord; fine hewn timber (mostly hard pine in long pieces) $30 per thousand feet, etc.

With the enormous resources in European Russia and Sweden, part of which are not even organized as yet, there is no apprehension of rapid advances in prices and no likelihood of scarcity of supply.

FINANCIAL RESULTS OF FOREST MANAGEMENT.

Concerning the financial results of forest management only the records of the State forests are accessible. It is clear that the income depends on the amount of timber cut and the prices obtained. If, therefore, the yearly cut has been increased, in some cases doubled, by good management since the beginning of this century, the income naturally is doubled. To this increase in amount of salable material there was added a general advance in prices, partly due to the depreciation of money in general, but vastly increased by the improvements in transportation, for which large sums have been expended, especially during the last fifty years.

The financial results of the various Government forest administrations vary considerably, as is natural, since market conditions vary much. It is believed that all these administrations are less profitable than they might be, being managed with great conservatism, and less for greatest financial result than for desirable economic results.

The following table exhibits in a brief manner the results of this kind of management, the figures referring to conditions in 1890 or thereabout. The record for the city of Zurich is added

to show how an intensively managed small forest property under favorable conditions of market compares with the more extensively managed larger forest areas:

Forestry statistics of certain German forest administrations, showing average cost of administration, gross and net income per acre, 1890.

States.	Forest area.	Total expenditure.	Revenue.		Expenditures and revenues per acre of forest.						
					Expenditures.						
			Gross.	Net.	Total.	Per cent of gross income.	Administration and protection.	Marketing crop.	Cultivation.	Roads.	Net revenue.
	Acres.										
Prussia	6,000,000	$8,000,000	$14,000,000	$6,000,000	$1.33	58	$0.48	$0.30	$0.14	$0.06	$0.96
Bavaria	2,300,000	3,150,000	5,880,000	2,730,000	1.37	53	.64	.37	.11	.11	1.19
Wurttemberg	470,000	1,025,000	2,260,000	1,235,000	2.17	45	.87	.92	.22	.33	2.63
Saxony	416,000	1,040,000	2,750,000	1,710,500	2.50	37	.65	.81	.11	.21	4.11
Baden	235.000	404,000	1,090,000	686,000	1.54	40	.32	.83	.15	.12	2.90
City of Zurich	2,760	14,000	26,000	12,000	5.00	54	1.14	2.10	.16	1.14	4.40

The latest figures (1897) show a considerable increase in all directions, expenditures, gross, and net income, over those prevailing ten years ago, and, as we will see further on in the discussion of the conditions in the single States, these increases have been steady for a long period.

The following figures represent the income and expense for State forests of the entire Empire and for the principal States as at present:

Financial results, 1897.

[Million dollars.]

State forests.	Gross income.	Total expenses.	Net revenue.
Germany *a*	39,361	18,833	20,528
Prussia	17,445	9,079	8,366
Bavaria	8.100	3,881	4.219
Wurttemberg	3,019	1,224	1,795
Saxony	2,865	1,032	1,833
Baden	1,337	618	719
Alsace-Lorraine	1,522	752	770
Hesse	840	405	435
Mecklenburg-Schwerin	609	356	253

a This item is a trifle below the truth, as the small principalities are here assumed to have no larger income than the average of the larger States.

From this statement it appears that Germany has a yearly gross income of nearly $40,000,000 from its State forests, i. e., from one-third of its total forest area alone, while the value of its forest products from the entire forest area (35,000,000 acres) may be estimated to sum up the handsome total of over $107,000,000, or round $3 gross income for every acre under forest cover.

The following table illustrates the results of forest management in the several States. For comparison the figures represent the yearly income and outlay per acre of total forest area, so that for instance the gross income of $3.47 per acre for Germany means that the German State forests yield each year about that sum for every acre of State forest, or $39,300,000 on the whole.

Yearly income and expenses per acre of forested area.

State forests.	Cut of wood per acre.	Gross income.	Expenses.		Net revenue.
			Total.	As a per cent of gross income.	
	Cubic feet.				
Germany *a*	62	$3.47	$1.66	48	$1.81
Prussia	54	2.66	1.38	52	1.28
Bavaria	72	3.71	1.78	48	1.93
Wurttemberg	81	6.50	2.64	40.5	3.86
Saxony	90	6.90	2.36	34	4.54
Baden	73	5.82	2.69	46.2	3.13
Alsace-Lorraine	57	4.24	2.09	49.4	2.12
Hesse	75	4.95	2.37	48	2.58
Mecklenburg-Schwerin	61	2.52	1.47	58	1.05

a This figure represents the average for 90 per cent of all State forests, and would be little changed if data for the other 10 per cent were accessible.

From these figures it appears that the several governments expend on an average about $1.66 per acre per year on their forest property, and that they obtain thereby a gross income of $3.47 per acre and a net revenue of $1.81, or 52 per cent of the gross income per acre per year. Considering the $1.81 as the interest on the value of the forest lands, and using the 3 per cent interest rate as customary for large investments, these figures show that by proper management the German States keep their poorest lands at a capital value of over $60 per acre; in other words, that the German State forests pay $19,000,000 for labor and taxes, and in addition pay interest at 3 per cent on a capital of $60 per acre. A large part of this land if deforested would not support a farmer and would rapidly degenerate into mountain pasture and heath, which at best could not be sold at over $5 per acre, and even then would prove more a detriment than advantage to the community. It also appears from the above figures that the revenue is largely in proportion to the expenses, that the forest which is best cared for also pays the best. The same conclusion is reached by a study of the past. In 1850, when the total expenses per acre in the Prussian forests were only 37 cents, the net income was only 46 cents; to-day it is $1.38 and the net income $1.28, and the same holds for other States. Thus Saxony expended 80 cents an acre per year in the beginning of this century and received 95 cents net income; to-day she spends $2.36 and receives $4.54, or nearly fivefold. That these advances are not merely the expression of higher prices for wood is clear from the fact that the average price of wood for the Prussian cut (300,000,000 cubic feet) has advanced since 1850 from $3.27 per 100 cubic feet to only $4.40, or 37 per cent, while the net income rose from 46 cents to $1.28, or 176 per cent.

Since so much has been argued as to the impossibilities and impracticability of employing these better forestry methods elsewhere, and especially since the idea of sowing or planting forests has at all times been ridiculed in the United States, it may be of interest to note just how Germany expends her money in the woods.

The following figures present the various large items as per cent of the gross income. Thus the total expenses in the Prussian forest use up 50 per cent of the gross income, the logging alone 14.8 per cent, etc.

The expenses represented the following proportions of the total income in per cent:

State forest of–	Total expenses.	Administration and protection (mostly salaries).	Cutting and moving the timber.	Planting, sowing, drainage work, wood roads, etc.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Prussia	52	21	14.8	7.5
Bavaria	48	24	20	6.6
Wurttemberg	40.5	12	14.6	8.6
Saxony	34	12	14.5	6.4
Baden	46.2	9.4	17.7	10.4
Alsace Lorraine	49.4	17	15.2	8.4
Hesse	48	19	21	9.7
Mecklenburg Schwerin	47	17	17.5	9.2

The above figures are doubly interesting, since they show that in Saxony, the very State where the timber is usually cut clean and the land restocked entirely by planting it with nursery stock, the item of planting, etc., uses up the smallest per cent of the total income—6.4 per cent.

From this brief outline it will be apparent that forestry in its modern sense is not a new, untried experiment in Germany; that the accurate official records of several States for the last one hundred years prove conclusively that wherever a systematic, continuous effort has been made, as in the case of all State forests, whether of large or small territories, the enterprise was successful; that it proved of great advantage to the country, furnished a handsome revenue where otherwise no returns could be expected, led to the establishment of permanent woodworking industries, and thus gave opportunity for labor and capital to be active, not spasmodically, not speculative, but continuous and with assurance of success. This rule has, fortunately, not a single exception. To be sure, isolated tracts away from railroad or water, sand dunes, and rocky promontories exist in every State, and the management of these poor forest areas costs all the tract can bring and often more; but the wood is needed, the dune or waste is a nuisance, and the State has found it profitable to convert it into forest, even though the direct revenue falls short of the expense.

FOREST ADMINISTRATION.

The care and active legislative consideration of the forest wealth dates back fully three centuries. The so called "Forstordnungen" (forest ordinances) of the sixteenth and seventeenth centuries laid the foundation for the present system, and in some States, like Wurttemberg, were never repealed, but merely modified to adapt them to modern views of political economy. The end of the seventeenth century brought much discussion into the subject of forest legislation, as in all other public affairs, and even conservative Germany was led beyond the point of equilibrium, and in most States the State supervision, especially of private forests, was abandoned. This led to the division and parceling of forest properties, and with the diminutive holding came mismanagement and to considerable extent the complete devastation. This condition never affected any of the State forests nor the majority of corporation forests, so that these properties continued on their way to improvement. The wretched condition of many of the private forests is deplored, exposed, discussed, but so far those States which gave the private forest free have been unable to do more than to teach by example and to encourage, both means entirely ineffective when, as is usually the case, the owner is too poor to handle a forest. What remains to be done is being done as fast as means and opportunity offer. The State buys these half wastes, restocks them at great expense, and thus public money pays for public folly.

To provide for a suitable and efficient forest service Germany has expended large sums in promoting forestry education. At nine separate colleges men are prepared for this work, and the forest manager ("Oberfoerster," "Revierfoerster") in any of the State forests is a college-bred man with a general education about equivalent and similar to that leading to a degree of bachelor of science in our better universities. The organization in all German States is similar—a central office at the seat of government, manned by experienced foresters, acts as advisor to the government, shapes the forest policy of the State, introduces all large measures of reform, etc., and acts as court of appeal in important forest cases. In each province, if the State is large (if not, the central office acts), a provincial forest office sees after the work of the province. This office cooperates with the forest managers in preparing plans for every piece of forest land, in determining the cut of the year, and it also examines the work as well as the records of every district, and acts as tribunal for the province in forest matters. But the real managers of the forests are the "Oberfoerster" or "Revierfoerster," each of whom has on an average about 10,000 acres of forest land for which he acts as responsible director. He lives in the forest, keeps himself informed as to all details, plans for every piece of ground (his plans must be approved by his superiors), and executes all plans. He determines where and when to cut, to plant, to build roads, and it is he who sells the forest products. In all cases he has a number of assistants and guards who act as police, and at the same time as foremen to the laborers, directing their work and keeping their time, or measuring their cut or work. The district which the Oberfoerster manages forms the unit in all records and transactions. All forest officials of any responsibility are employed for life or good behavior, their requirements, duties and rights, rates of pay, pension, etc., are all clearly set forth in the forest laws of every State.

In the following pages the conditions and results of forest management in the leading States are fully set forth, based upon the latest official data available.

FOREST MANAGEMENT OF LEADING STATES.

PRUSSIA.

The Kingdom of Prussia, with its 30,000,000 people and an area of nearly 90,000,000 acres of land, representing all natural conditions from the low coast plain to the precipitous mountain system, with its busy centers of manufacture and commerce and its distant rural provinces, stands out to day as the strongest example of the great benefits of scientific forestry.

The forests of Prussia cover 8,192,505 hectares (about 20,300,000 acres), or 23.5 per cent of the total area. This proportion of forest varies for different parts of the Kingdom from 16 per cent to 39 per cent; it is below the average of 23 per cent in seven provinces, of which only Schleswig-Holstein falls below 16 per cent, and is above the average in six provinces, some of which, like Brandenburg, belong to the densely populated portions of the Kingdom. The area relations

have remained practically constant for about thirty years, there being then as now in forest 20,000,000 acres; cultivated 42,000,000 acres, or about twice as much cultivated land as forest.

Of the forest area, 8 per cent belongs to the crown, 30 to the state, 12.5 to villages or municipalities, 1 to Stiftungen (Fonds), 2.7 to corporations, and 52.9 to private owners. This ownership relation has changed a trifle during the last twenty years, the state and municipal forests having gained a little over 1 per cent at the expense of the private and corporation forests.

Situated between latitude 49° to 55° N. and longitude 23° to 40° E. and occupying portions of the extensive coast plain along Baltic and North seas, as well as covering parts of nine separate mountain chains, the forests of Prussia naturally display considerable variety. Of the total 20,000,000 acres, about half falls to the plain, one-fourth to the hilly, and one-fourth to the regular mountain districts. The climate is moderately cold; the mean or average temperature for summer is about 60° to 65° F., varying but little for the different parts of the Kingdom, and being quite uniform for all three summer months. Spring and fall, the latter a trifle warmer and more even than the former, have a mean temperature of about 45° F., while that of the winter months is generally near the freezing point, the coldest weather for any one place and month being rarely below 25° F.

Prussia is a moderately humid country. The records from thirty to seventy years indicate an even distribution of precipitation, varying generally between 22 and 28 inches, reaching a height of over 32 inches, and only 3 out of about 40 stations. With regard to the manner of management, the kind of timber raised, and the financial results of the work, the State forests, for which alone exact statistics exist, may serve as examples, though the results are somewhat better in these than in the forests of municipalities and private owners.

The total area of State forest in 1893 was 2,464,757 hectares, or about 6,750,000 acres. This total area has remained almost unchanged for over thirty years. During this time many large and small tracts have been sold or exchanged to round off the State holdings and to satisfy private rights, many of which had become extremely troublesome and proven a great hindrance in the proper management of the woods. These sales and exchanges were fully balanced by purchases, especially of poor, unproductive private forests and heath lands, for which purpose of late the State appropriates annually the large sum of 1,000,000 marks ($250,000), the policy of increasing the State holdings having been steadily pursued for more than fifty years. About two-thirds of the State forests are situated in the North German plain, though some occur in every province of the Kingdom.

Of these State forests 97 per cent are regular timber forest, mostly pine and spruce, where the final crop is intended to furnish saw timber, and every particular parcel is supposed to be stocked with trees of nearly the same age. Only one-half of 1 per cent is managed as "Plenterwald" with the method of selection where trees of all sizes and age mingle together on the same parcel and the logging merely involves the selection of suitable sizes. One-half of 1 per cent is standard coppice, where the bulk of the trees, commonly hard woods, are cut off while still small, 15 to 30 years old, while a small portion is left over to grow into larger sizes; and 1.7 per cent is managed as coppice, largely oak coppice for tanbark, where the trees (only the sprouting hard woods) are cut down every ten to twenty-five years, the wood being utilized chiefly as poles and fuel. Of the timber forests, 62 per cent is stocked with pine, almost entirely Scotch pine (*Pinus sylvestris*), furnishing hard pine similar to our red or Norway pine, 16 per cent is beech, 12 per cent spruce, and nearly 6 per cent oak forest. Thus about 75 per cent of all Prussian State forests are coniferous woods and only about 25 per cent stocked with hard woods, principally oak and beech.

In general the trees of the timber forests are cut at an age of about 100 years (a 100-year rotation). At present 13 per cent of the area is stocked with trees over 100 years old; 13 per cent, 81 to 100 years old; 14 per cent, 61 to 80 years old; 18 per cent, 41 to 60 years old; 19 per cent, 21 to 40 years old; 19 per cent, 1 to 20 years old, and about 4 per cent are cut clean (recent fellings) to be reforested at once.

SAXONY.

If Prussia may be regarded the best example of the success of rational forestry in a large country, and Wurttemberg can be cited as proving the great value of a very conservative, almost paternal, attitude of the State with regard to its forests, surely Saxony deserves the credit of leading all other countries in the intensity of its forest management.

The total area of the State is 3,700,000 acres, and its population 3,182,000, and its total forest area about 1,020,000 acres, or 27 per cent. Of this forest area, 173,889 hectares, or nearly 430,000 acres, equal to about 43 per cent of all forests of the country, belong to the State. The accurate records for these State forests have been kept for more than eighty years, and fully illustrate the development and growth of forestry in the Kingdom. The bulk of the forests are mountain forest; 91 per cent in conifers, mostly spruce, and only 9 per cent in hard woods, most of which is beech; while only about 4 per cent is nonproductive rock and water area.

As early as 1764 the State of Saxony began the improvement of the then rather dilapidated forest properties. The real systematic work of forest survey and management, however, did not begin until Heinrich Cotta (often called the father of modern forestry) began his noteworthy efforts in 1811. Though the Government never appropriated special funds for the increase of its forest holdings, the money which accrued from the sales of other State lands, as well as roadways, building sites, etc., sufficed to increase the area during the past eighty years by fully 16 per cent, the growth being a slow, steady one, fully illustrating the policy of the Government.

Thus the growth was: 1836 to 1846, 5,000 acres; 1846 to 1853, 5,000 acres; 1853 to 1863, 5,000 acres; 1863 to 1873, 17,200 acres; 1873 to 1883, 17,200 acres; 1883 to 1893, 12,500 acres.

As in all German States, nearly every piece of State forest was burdened by rights of private persons and corporations, for which Saxony has paid, almost entirely in cash, the handsome price of $1,300,000.

During the last sixty years the area stocked with conifers has steadily grown from about 310,000 to over 385,000 acres, and the area of beech and other hard woods except oak has been proportionately diminished, the hard woods all told covering at present only about 14,000 acres, or a little over 3 per cent of the forest area. The condition of the forests, though, of course, very good at the start, if compared to ordinary wild woods, has steadily improved since 1817, in spite of the fact that each decade a larger amount of wood was cut.

The following figures serve to illustrate this important fact and at the same time show that there has not only been a steady increase in the total amount of wood standing and the amount cut, but that the larger sizes form to-day a much greater per cent than formerly:

Years.	Total amount of wood cut each year (average for each decade).	Per acre of forested area.			
		Amount cut.			Amount standing per acre on total area.
		Total.	Wood over 3 inches thick (cord wood and timber).	Timber (not cord wood).	
	M. cub. ft.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
1817-1826	21,400	60	40	7	....
1827-1836	21,800	61	39	10	....
1837-1846	20,400	56	36	11	....
1847-1853	23,500	64	44	14	2,120
1854-1863	26,000	70	48	23	2,280
1864-1873	31,600	82	60	37	2,480
1874-1883	36,600	90	66	47	2,650
1884-1893	37,400	90	68	54	2,620

From these figures it appears that the cut on the whole has increased from 21,000,000 cubic feet to 37,000,000, or by fully 57 per cent, and the cut per acre and year of total forest area from 60 cubic feet to 90 cubic feet, or exactly 50 per cent. Moreover, of the 90 cubic feet per acre in 1893 there were 68 cubic feet, or 75 per cent, wood over 3 inches (excluding stump wood), while from 1817 to 1826 only 66 per cent was over 3-inch stuff. But what indicates even more strongly the effect of better management is the fact that more than half of the cut of 1893 was sold, not as cord wood, but as timber (saw timber, etc.), while even as late as 1865 only a fourth could thus be utilized, though the manner of selection (inspection) has changed but little since that time. That with all this intense utilization of the forest the standing timber should increase instead of becoming exhausted is perhaps the strongest example of the success of scientific forestry and one which in this country would scarcely be believed possible by most of the lumbermen and woodsmen.

Practically, all State forests are timber forests and the prevalent method of treatment has for a long time been the "kahlschlag" method of cutting, where all trees are cut at the harvest and the bare area is at once planted with nursery stock. The expenses for cultural work all told,

including maintenance of nurseries, seed and plant purchases, as well as planting, amount to only 12 cents an acre per year, or 1.8 per cent of the gross income, while for the last twenty years more than twice this sum has been expended for construction and improvement of roads, the great value of which are nowhere more fully recognized than in busy Saxony.

The financial results are exhibited in the following table:

General financial results in the State forests of Saxony.

Years.	Annual income (gross).	Annual expense.	Annual net income.	Per acre and year of total forest area.		
				Income (gross).	Expense.	Net income.
1817-1826	$649,000	$297,000	$352,000	$1.75	$0.80	$0.95
1827-1836	692,000	321,000	371,000	1.86	.86	1.00
1837-1846	761,000	342,000	419,000	2.02	.90	1.12
1847-1853	976,000	388,000	588,000	2.56	1.02	1.54
1854-1863	1,368,000	443,000	925,000	3.53	1.14	2.39
1864-1873	1,986,000	563,000	1,423,000	4.91	1.39	3.52
1874-1883	2,624,000	875,000	1,749,000	6.23	2.08	4.15
1884-1893	2,890,000	996,000	1,894,000	6.66	2.29	4.37

The extraordinary results indicated in the above table can not entirely be credited to the increase of wood prices and the general depreciation of money during this century; they are primarily the monetary expression of the improvements indicated in the previous tables; they mean increased sales, and sales of older, larger, and better material.

When it is considered that Saxony has taken in about $190,000,000 during the last fifty years from a small area of rough lands (left waste in many countries, even in Europe), a tract of land half the size of a good county in Wisconsin, the great advantage of a careful treatment of forest areas must become clear to everyone. Considering the net income as the interest of the value of the forest lands at the prevailing 3 per cent rate, the table shows that scientific care has increased the value of these poor mountain lands from $100 to $150, whereas their deforestation would quickly convert them into poor alpine pastures which would bankrupt their owners at $10 an acre. The table also shows clearly that it is not accident, not merely a general improvement of the country, but that it is careful, systematic work which has led to these improvements. When Saxony spent only $1 on each acre of forest land she received only $1.54 net income; when she spent $2.39, her net income was more than doubled, reaching during the ten years ending 1893 $4.37.

The following figures illustrate the nature and relative importance of the expenses per acre as compared with the income, as well as the prices obtained for the material:

Decade ending—	Price per cubic foot of wood over 3 inches.	Wood cut.	Gross income.	Total.	For administration and protection.	Felling and moving timber, etc.	Planting and other cultural work.	Roads.
	Cents.	*Cubic feet.*			*Cents.*	*Cents.*	*Cents.*	*Cents.*
1826	4.2	60	$1.75	$0.80	38	30	8	2
1836	4.7	61	1.86	86	40	31	8	5
1846	5.6	56	2.02	90	44	31	10	4
1853	6.0	64	2.56	1.02	47	37	11	5
1863	7.4	70	3.53	1.14	49	45	13	6
1873	8.1	82	4.91	1.39	54	62	10	11
1883	9.4	90	6.23	2.08	77	92	13	24
1893	9.9	90	6.66	2.29	93	95	14	26

From the above it appears that the prices of wood have doubled since 1817, but that during the last twenty-five years they have remained practically constant. Part of this advance is due to the general advance of prices, but part also to the improvement of the material sold. The advance in the expenditure for administration since 1846 is due both to the advance in wages and salaries generally (seen also in the advance of cutting expenses), but is also due to the greater competence of the administration. Saxony, unlike Michigan and other States of this Union, prefers to spend the money in protecting its forest rather than saving the expense and losing the property. Of special interest is also the fact that even in this intensive management, where almost every acre is reforested by planting with nursery stock, the cultural operations, including drainage and kindred expenses have varied only within a few cents per acre, involving during

the last thirty years generally less than 2 per cent of the gross income. To many in this land of forest fires it may perhaps be remarkable that this general enemy and its destructions have not been of sufficient consequence to deserve compilation for this general statement. These mountain forests of spruce and pine are simply not allowed to burn up.

The management of the forests of Saxony is similar to those of Prussia. While those of the State are under conservative and most efficient care, those of private persons and corporations are practically free; the only thing the State authorities do is to give good example, assist private individuals, etc., by furnishing cheap plant material from the forest nurseries and to prepare plans for the management of forests if such plans are asked and paid for.

BAVARIA.

The kingdom of Bavaria has a total area of about 18.8 million acres, or little more than half that of the State of Wisconsin, supporting a population of about 5,589,000 people. It comprised about 10,500,000 acres, or 56 per cent, of fields and gardens; 750,000 acres, or 4 per cent, of pasture lands; 6,350,000 acres, or 34 per cent, of forest; 1,200,000 acres, or 6 per cent, of unproductive land, largely mountains, roads, and water surfaces.

On the whole, this relation of areas has not changed materially in over thirty-five years, so that in 1893 the total area of forest lands is given at about 6,200,000 acres, or at 35.1 per cent of the entire land surface.

Of these 6,200,000 acres there are: State forests, 2,160,000 acres, or 34.8 per cent; corporation forests, 780,000 acres, or 12.6 per cent; pond forests, 110,000 acres, or 1.7 per cent; private forests, 3,150,000 acres, or 50.9 per cent.

The forest laws and forest organization resemble those of Baden and Wurttemberg. The private forests are under State supervision, clearing of forest lands requires a permit, the mismanagement or devastation of a forest property is forbidden, and devastated forest areas are to be reforested by the State and the expense charged to the forest. All corporation and Fonds forests are under direct control of or are managed under control of the State forest authorities, so that fully one-half the forest area of Bavaria is under careful treatment. As with all German States, Bavaria constantly endeavors to increase the State holdings, and deteriorated and other forest properties are bought up as opportunity offers. During the fifty years ending 1894, the State purchased about 144,000 acres, at a cost of $5,577,000, or about $38 per acre. Besides this increase of territory, the State has, during this same period, expended about $3,800,000 in the purchase of easements or servitude, involving 10,716 separate cases of privileges to timber and firewood. Nevertheless, there are still many of these privileges or servitudes, which require an annual outlay of over $400,000 and thus represent a capital value of over $10,000,000.

The distribution of the forests over the kingdom is rather an even one. Six of the eight provinces have over 30 per cent, the lowest 22 per cent of forest area, while the highest 38 per cent. Of the entire forests area about 90 per cent is covered by timber forest, where the timber is cut usually at about 100 to 120 years, and only 9.4 per cent as coppice and standard coppice.

Forty years ago the same was stocked as follows:

	Timber forests.	Coppice and standard coppice.	Selection timber forests.
	Per cent.	*Per cent*	*Per cent.*
State forests	92	5	3
Corporation forests	62	35	3
Private forests	72	12	14
True average for the whole area	78.5	12.7	8.4

The principal forest trees are the conifers, chiefly spruce. Of the total, about 46.2 per cent is spruce and fir, 30 per cent pine, 9.7 per cent beech, 4 per cent oak (two-thirds oak-bark coppice), 2.3 per cent other hard-wood timber, 6.8 per cent other hard-wood coppice.

Thus, conifers represent about 77 per cent, the hard woods 23 per cent. The conifers are primarily the trees of the mountains, the hard woods, beech particularly, being most abundant in

the valley of the Rhine, the Palatinate, and Lower Franconia, where the beech forests cover as high as 80 per cent of the forest area.

In 1860 the total cut for the kingdom was 275 million cubic feet of stem wood, 35 million cubic feet of branch wood, 30 million cubic feet of stump wood, making a total of 340 million cubic feet, and was divided as follows:

	Per cent of total cut.	Yield per acre.
		Cubic ft.
State forests	39	58
Corporation forests	14	46
Private forests	46.5	47
Total	100	51

For the State forests alone the cut in 1894 of wood over 3 inches, excluding branch and stump wood, was 55 cubic feet per acre, and included saw and other timber, 55 million cubic feet; cord wood (exclusive of branches and stumps), 64 million cubic feet.

The financial results for the 2.16 million acres of State forests were, in 1894: Total income, $8,100,000, or $3.71 per acre; total expense, $3,881,000, or $1.78 per acre; net income, $4,219,000, or $1.93 per acre.

Compared to other small States of Germany, particularly Saxony and Wurttemberg, the net revenue per acre of forest is decidedly low; but it must not be forgotten that a considerable part of these State forests is situated in the high Alps, where the difficulties of removing the timber have so far been very great, and the value of timber consequently very small. Thus, fine timber trees, worth $50 to $100 on the markets of the lower Rhine, are worth little over $1 apiece in these Alpine districts.

As might be expected, the permanent improvements of the forests, particularly the construction of highways and roads, still require large sums every year. Thus, in 1894, Bavaria spent over 1,000,000 marks ($250,000) on road construction.

The management of the forests is quite similar to that of the other German States. The Revierförster, corresponding to the Prussian Oberförster, is the responsible manager of each district. The districts are quite large; they include usually about 5,000 acres of State forest, so that one Revierförster is usually 6 to 10 miles from his neighbor.

For all State and corporation forests, an area of a little over 3 million acres, there are 609 Revierforster or managers, 1,589 guards and assistants, besides 175 accountants and 107 superior officials. The manager or Revierförster makes and executes the plans and keeps the records for the woods of his district.

As in Wurttemberg, rational measures for the proper use and treatment of forests of Bavaria date back to the beginning of the seventeenth century. As early as 1616 a forest law was passed which embodied all that seemed at that time desirable. This law was modified, some complications arising from the change of size and form of the kingdom, and also through the radical views promulgated during the second half of the eighteenth century. On the whole, however, Bavaria remained conservative, which in view of its large mountain forests must be regarded as particularly fortunate.

The establishment of the forest school at Munich took place about 1789, when a general reorganization occurred, and the functions of the forester changed from those of a hunter to those of a producer of timber.

WURTTEMBERG.

This little State, with an area of about 4,820,000 acres, or about one-seventh that of Wisconsin, and a population of little over 2,000,000 people, ranks among the most conservative as well as the most successful among the commonwealths of Europe. In matters of forestry this State began proper measures as early as 1614, when laws were inaugurated for the proper treatment of forest properties, which remain fundamental to this day. These early laws, which made the proper care of forests obligatory to all and forbade both forest devastation and clearing (the latter possible only on permit), were properly enforced and maintained even through the

troublesome times of the end of the eighteenth century. They were remodeled and perfected to suit modern conditions in 1875 and 1879 the law of the former date dealing with the forests of public corporations, the latter with State and private forests in general.

The "forest police law" of 1879 requires:

(*a*) Clearing of forest requires a State permit; illegal clearing is punished with a fine.

(*b*) A neglected piece of forest shall not become waste land; the State authority sees to its reforestation, with or without help of owner, the expenses to be charged to the forest.

(*c*) If the forester is convinced that a private owner cuts too much wood or otherwise mismanages his forest, he is to warn the owner, and if this warning is not heeded the forest authority may take in hand and manage the particular tract.

(*d*) Owners of small tracts of forest can combine into associations and can place their properties with municipal or even State forests for protection and management. In the latter case they share the advantages of part of the municipal or communal forests which are managed by State authorities.

The law of 1875 relating to the management and supervision of forests belonging to villages, towns, and other public corporations places the forests under this category all under direct State supervision; there being a special division of corporation or municipal forests in connection with the State forest bureau. The law demands that all corporation forests be managed in accordance with the principles of a continued supply, the same as the State forests. The corporation may employ its own foresters, but these must be approved by the forest bureau and are responsible for the proper execution of the plans of management. These plans are prepared by the foresters and must be approved by the State forest authorities. If preferred, the corporation may leave the management of its forests entirely to the State authorities. This is always done if a corporation neglects to fill the position of its forester within a certain period after it becomes vacant. Where the State forest authorities manage either corporation or private forest, the forest is charged with 8 cents per acre and year for this administration. This fee is generally less than it costs, so that the State really has been making a sacrifice so far in providing a satisfactory management for these forests.

As in all other German States, nearly every piece of forest land was formerly encumbered with certain rights which entitled the holders to certain fixed amounts of firewood, timber, to pasture live stock, etc. The law of 1848 obliges the holders of these rights to part with them if the proprietor pays the value of the rights, the manner of ascertaining the value being set forth in the law itself. Thus, for the right of cutting his supply of firewood in a forest the holder of the right is paid a sum which if placed at 4 per cent interest will purchase as much wood as the holder of the right used per year, the average of twelve seasons being the criterion. Of the different rights or privileges, those concerning pasturage and the cutting of hay in the forests are practically settled, and the State paid between 1873 and 1880 about 2,445,000 marks, or $611,000, for these rights. For privileges of cutting wood and timber the State has expended large sums. Even prior to 1848, between 1825 and 1850, forest land valued in the aggregate at about $3,000,000, and between 1850 and 1880 over $500,000 more have been paid out to rid the woods of these pestiferous rights, and yet as late as 1873 these rights were worth $32,000 per year, or a capital (at 4 per cent interest) of $800,000.

In matters of taxation all forests are assessed according to the net revenue which they produce. Of the total area of the land, about 42 per cent is plow land, 18 per cent meadows and pastures, 31 per cent forest, 3 per cent gardens and vineyards, and 2 per cent roads. In its distribution over the State the forest forms 27 per cent of the area of the Nekar Kreis, 39 per cent of the area of the Schwarzwald Kreis, 31 per cent of the area of the Jaxt Kreis, and 25 per cent of the area of the Donau Kreis.

Of the total of about 1,470,000 acres of forest, 480,000, or 32 per cent, belong to the State; 470,000, or 32 per cent, to corporations, and 530,000, or 36 per cent, to individuals.

Of the corporation forests, nearly 360,000 acres are managed by State foresters; of the private forests, 200,000 acres are held by the nobility, including the royal family.

Accurate statistics have been prepared so far only for the State forests and of late also for the corporation forest, so that a more detailed description of these classes must serve as illustration for the whole.

The State forests of 480,000 acres occupy parts of all four provinces of the country. About 92 per cent lie between 900 and 2,400 feet altitude; 42 per cent are stocked on level ground, 29 per cent on gentle slopes, and about the same amount on steep declines. Over 40 per cent of these forests are situated on sandy soils, and the rest are largely on the poor limestone soils of the Jura, and only a small part on the drift formation skirting the north side of the Alps.

Of the State forest area there is covered by a pine growth of spruce, 28 per cent; beech, 20 per cent; fir, 9 per cent; pine, 7 per cent; mixed growth of conifers, 14 per cent; conifers and hardwoods, 9 per cent; mixed hardwoods with oak, 7 per cent; mixed hardwoods without oak, 2 per cent. Thus about 60 per cent is coniferous growth and only 30 per cent hardwoods, with about 9 per cent mixed timber.

Fully 97 per cent of the State forests are managed by the timber forest system. The rotation is for timber forest, 100 years for 74 per cent of the area; 80 years for 24 per cent of the area, and 120 years for 2 per cent of the area.

At the present (1894) the areas containing timber over 100 years old cover 11 per cent of the area; 81 to 100 years old cover 15 per cent of the area; 61 to 80 years old, 15 per cent; 41 to 60 years old, 17 per cent; 21 to 40 years old, 19 per cent; 1 to 20 years old, 23 per cent; so that a fairly regular distribution for a 100-year rotation exists.

These timber forests yield about 56[1] cubic feet per acre of timber from the main cut or harvest and 11 cubic feet per acre from thinnings, making in all 67 cubic feet per acre and year for the entire area. The 3 per cent managed in coppice and standard coppice cut only about 14 cubic feet per acre and year.

The total cut for 1894 was, for wood over 3 inches thick: Oak, 1,200,000 cubic feet, or 3.9 per cent; beech and some other hard woods, 7,900,000 cubic feet, or 26 per cent; conifers, 21,500,000 cubic feet, or 70 per cent.

This cut was composed of—

A.—*Timber generally over 6 inches at the top end.*

	Amount.	Per cent.
	Cubic feet.	
Oak	560,000	3.8
Other hard woods	420,000	2.8
Conifers	13,800,000	94
Total	14,780,000	100

B.—*Poles 2–6 inches, 3 feet from butt end.*

	Amount.	Per cent.
	Cubic feet.	
Oak	1,500	0.2
Beech and other hard woods	6,400	.9
Conifers	685,000	99
Total	692,900	100

C.—*Cordwood.*

	For wooden ware.	For firewood.
	Cubic feet.	*Cubic feet.*
Oak	46,000	590,000
Beech and other hard woods	78,000	7,400,000
Conifers	295,000	6,450,000

The above figures, especially those for the yield in saw and other timber, clearly point out the great advantage of the conifers over the hard woods. The same is also clearly illustrated by the fact that the material sold as firewood forms only 40 per cent in conifers, but 94 per cent in

[1] This means that if the timber is 100 years old, as most of it is, each acre of forest cuts 5,600 cubic feet of wood at time of harvest.

beech and other hard woods, leaving out the oak. Moreover, the yields have been much greater for conifers than beech.

Thus the yield for material over 3 inches thick in the hard woods was only 51 cubic feet per acre and conifers 74 cubic feet per acre, while the average value of the two is about as 5 for beech and other hard woods, leaving out oak, to 8 for coniferous wood, so that the yield in money per acre for the two was more nearly 2.4 times as great for conifers as for hard woods.

The prices obtained for wood, generally delivered at the main roads, was: Timber, oak (white oak), 25 cents per cubic foot; conifers, 11.7 cents per cubic foot. Cord wood, beech, 4.9 cents per cubic foot, or $6.30 per cord; conifers, 3.6 cents per cubic foot, or $4.60 per cord.

The money results were for 1894 as follows:

Gross income	$3,019,000, or 100 per cent
Total expense	1,224,000, or 40 per cent
Net income	1,795,000, or 60 per cent

or per acre of forest area:

Gross income	$6.20
Expenses	2.51
Net income	3.69

this latter forming 59 per cent of the gross revenue.

Among the expenses were conspicuous:

Felling of timber	$397,000
Administration and protection	339,000
Roads, new, and repair	163,000
Taxes	103,000
Planting, sowing, etc	91,000

The following figures illustrate the progress of the last eighty years, and at the same time indicate how steadily this small area of otherwise almost valueless land has been made to furnish an ample supply of timber and a handsome revenue:

Results of forest management in the State forests of Wurttemberg.

Year.	Forest area.	Wood over 3 inches thick cut each year.	Price per cubic foot.	Per acre and year.[a] Net income.	Per acre and year.[a] Cut wood over 3 inches.
	M acres.	*M cubic feet.*	*Cents.*		*Cubic feet.*
1815	....	....	....	$0.30	....
1819	472	....	....	.42	....
1823	....	15,200	....	.52	33
1828	469	17,200	....	.64	37
1834	445	17,700	....	.85	39
1841	447	25,000	....	1.78	55
1845	452	25,400	....	1.93	55
1850	452	23,800	....	1.11	52
1855	455	26,600	4.3	1.42	58
1860	457	28,400	7.5	3.22	61
1865	460	25,300	9.7	3.54	54
1870	465	26,600	7.5	2.62	57
1875	467	28,800	10.7	4.21	61
1880	471	28,700	8.0	2.66	60
1885	474	29,400	8.1	2.90	61
1890	476	30.200	8.7	3.33	63
1894	480	30.600	9.3	3.69	63

[a] Refers to entire forest area—swamp, water, surfaces, and all.

Most of the logging is done by the cubic foot or cord, and the prices are about 60 to 65 cents per 100 cubic feet of coniferous and 80 cents per 100 for hard-wood timber, while cord wood is generally worked up for about $1 per cord, including piling at roadway. All cut-over land is at once reforested. During 1894, 275 acres were thus recovered by seeding and about 6,000 acres by planting, the latter being thus generally the rule, especially in the coniferous districts. The total expenses of cultural work were $88,000, or less than 3 per cent of the gross income.

The thinnings of the dense sapling timber involved during the year about 20,000 acres and furnished about 240 cubic feet of wood per acre. Most of this material in the hard-wood district has to be cut into inferior firewood, but the spruce, fir, and pine can usually be sold as poles and pulp stuff, etc.

Though largely stocked on sandy soils and composed of pine and other conifers, there are no forest fires reported for the year. The administration of forests is in the hands of "Revierfoerster," corresponding to the Prussian "Oberfoerster," who prepare the plans and execute them, being assisted by a body of subalterns. The district of a Revierfoerster covers about 10,000 acres of forest, while the range or "hut" of the forest guard is generally about one-tenth of this. These guards also serve as foremen in all cultural and felling operations, but the Revierfoerster is supposed to keep fully informed on all details and preserve accurate record. Besides their duties as State forest officers, it is expected that these men also keep themselves informed as to the condition of private and other forests.

BADEN.

In this intensively cultivated little State, with a total area of only about 3,720,000 acres, supporting a population of 1,656,000, the forests occupy over 37 per cent of the entire land surface. The forest area has increased between 1880 and 1895 by over 50,000 acres, being in the latter year 550,891 hectares, or about 1,360,000 acres. These forests were owned as follows:

Owner.	1895.	1880.
	Acres.	*Acres.*
State	237,000	232,000
Villages and towns	620,000	610,000
Other corporations	47,000	33,000
Private persons:		
Nobility	147,000	147,000
Others	310,000	285,000

The forest policy of Baden has been conservative and there is no State in Germany where the general conditions of the forests are better. Since all municipal and corporation forests are under direct State control, being managed by the State forest authorities, about 910,000 acres, or over 60 per cent of all forests, enjoy a careful, conservative treatment, which insures to them the largest possible return in wood and money. But even the private forests are under the supervision of the State authorities, and though the private owner may use his forest very much as he pleases he can in no way devastate or seriously injure it. Clearing requires a permit, also a complete clearing cut, which latter is permitted only if the owner guarantees the reforestation of the denuded area within a given time. Bare and neglected spots in forests must be restocked, and failure of private owners to comply with the forest rules and laws leads to temporary management of the forest by the State authorities, such management never to continue less than ten years. Of the State forests there are about 93 per cent timber forest with a rotation of eighty to one hundred and twenty years and only 7 per cent coppice and standard coppice intended to produce tanbark and firewood. Of the corporation forests about 83 per cent are timber forest, so that of all the forests under State management about 85 per cent are timber forest managed on long rotations and furnishing large returns.

Of the State forests, 21 per cent are hardwoods, with little or no conifers; 30 per cent are mixed forests, hardwoods, and conifers in about equal parts; 49 per cent are coniferous forests, the bulk being stocked with spruce and fir, while only about 4 per cent of the total is stocked with pine alone.

Full and accurate statistics existing only for the State forests, and, as far as the annual cut is concerned, for corporation forests, the following figures apply only to about 60 per cent of the forests of the country.

The cut for 1894 was in—

	State forests.	Corporation forests.
A. From timber forests:	*Cubic feet.*	*Cubic feet.*
Main crop	11,100,000	29,100,000
Thinnings	4,500,000	9,800,000
Stumps	150,000	330,000
B. From coppice and standard coppice:		
Main crop	780,000	7,600,000
Thinnings	30,000	120,000
Stumps	....	50,000
	16,560,000	47,000,000

This same cut per acre of total forest area is—

	Cubic feet.
Timber forest:	
State	74
Corporation	71
Coppice and standard coppice:	
State	53
Corporation	66

This enormous yield of nearly 64 million cubic feet of wood Baden has obtained from this small area for many years without in the least decreasing the amount of standing timber or wood capital. In the State forest the cut per acre since 1867 has never been less than 57 cubic feet per year, or since 1885 has never fallen below 71 cubic feet, while twice since 1870 it has been over 85 cubic feet per acre and year.

Of the total of nearly 64 million cubic feet, 19,200,000 cubic feet are timber and other wood not sold as fire or cord wood, and 29,100,000 cubic feet are cord wood over 3 inches.

The forests of Baden are generally well located, and the State has long realized the great importance of good highways, so that the prices for timber are generally good and the income from the woods correspondingly high.

The following prices in the woods were obtained in 1894:

For round timber long lengths and saw logs (per cubic foot):	
Oak	$0.16 to $0.39
Beech	.15
Ash and maple	.24
Birch	.08
Alder	.23
Other hardwoods	.16
Conifers, long stems	.07 to .13
Conifers, saw logs	.11 to .14
Conifers, railway ties	.08
For cord wood (per cord):	
Beech	6.50 to 8.40
Oak	5.80 to 10.80
Other hardwoods	6.30 to 7.80
Conifers	4.00 to 4.80

The financial results in the State forests were as follows:

For the year 1894—	
Total income	$1,337,000
Total expenses	618,000
Net income	719,000
Or per acre of forest-stocked area—	
Gross income	$5.82, or 100 per cent
Expenses	2.69, or 46.2 per cent
Net income	3.13, or 53.8 per cent

How steadily this handsome revenue has been received may be inferred from the fact that during the twenty-eight years ending 1894 the gross income has never been below $4.24 per acre; that for thirteen out of the twenty-eight years it varied between $4.24 and $5; that twelve years it was between $5 and $6, and three years above $6 per acre.

The following figures show this relation for the period 1881 to 1894:

Production and cost per acre of forested area.

Year.	Cut.	Annual income (gross).	Annual expense.	Annual net income.	The expense is of the income—
	Cubic feet.				*Per cent.*
1881	59	$4.08	$2.13	$1.94	52
1882	62	4.41	2.17	2.24	49
1883	67	4.80	2.24	2.55	47
1884	67	4.87	2.30	2.57	47
1885	71	5.15	2.34	2.80	45
1886	74	5.23	2.47	2.76	47
1887	85	5.33	2.60	2.73	49
1888	75	5.16	2.50	2.65	49
1889	76	5.48	2.59	2.88	47
1890	80	5.85	2.60	3.25	44
1891	74	5.65	2.58	3.06	46
1892	73	5.73	2.65	3.08	46
1893	72	6.07	2.64	3.42	43
1894	73	5.82	2.69	3.13	46

Considering the fact that these forests, in the aggregate only about as large as ten townships, are scattered over considerable area, and thus their protection and management is rendered much more costly than if in more compact form, these results are certainly most remarkable.

Of the expenses, those of special interest are:

Logging (generally)	$221,000
Administration	132,000
Protection	54,000
Roads, new and repair	77,000
Sowing, planting, etc	42,000

As stated before, wherever the forest is cut, reforestation is at once begun. As in other States, part of this is carried on by the process of natural regeneration, where the old trees are never entirely removed until they have been made to seed the ground, but part is also done by artificial sowing and planting. In 1894 about 125 acres were seeded anew; 65 acres were seeded to correct failures of former years; 760 acres were planted for the first time, and about 850 acres of former failures were corrected.

The work of seeding costs $11.95 per acre, the planting $11.43 per acre, which shows that it is not by a penny-wise and pound-foolish system of retrenchment that the most extraordinary results of the Baden forest management are attained.

ALSACE AND LORRAINE.

These two small provinces, formerly under French rule, have an area of about 3,600,000 acres and a population of about 1,500,000, and are under the Imperial Government. The existing forest laws of these provinces were left in force on their transfer to Germany, so that now, as in former times, the French "code forestier" of 1827 and some subsequent dates decide in all affairs concerning the forests. The laws in the main are like those of Baden; they restrict the right of the private owner to a proper use of the forest and forbid all devastation; any clearing requires a State permit, and with regard to protection against fire, insects, etc., they are subject to the ordinary forest police regulations. As in Baden, the forests of corporations are managed by State authorities, so that a well-planned forestry system applies to all forests except those of private owners, and even these are under rigid supervision and partial control.

The total area covered by forest is 444,466 hectares, or about 1,100,000 acres, forming about 30 per cent of the entire land surface. Of this forest area there belong to the State 340,000 acres, or 31 per cent; villages and towns, 490,000 acres, or 45 per cent; private owners, 220,000 acres, or 20 per cent. Besides these there are about 40,000 acres of land belonging jointly to the State and villages and 6,000 acres belonging to corporations other than municipalities.

Since all forests, except those of private owners, are under the management of the State forest authorities, fully 80 per cent of the forests of these provinces are in most excellent condition. Though the exact proportion has not been ascertained, it may be said that about 60 per cent of the forests are hardwoods, largely beech and oak, and only 40 per cent conifers.

The total cut for 1891 was—

	Cubic feet.
For State forests	21,400,000
For corporation	33,000,000
Total	54,400,000

of which about 17,500,000 cubic feet was nutzholz, or timber not sold as cord wood or firewood.

Of the 21,000,000 cubic feet of wood cut in the State forests there were in 1891:

Kind of wood.	Timber (nutzholz).	Cord and other firewood.	Total of wood.	Per cent of total cut.
	Cubic feet.	*Cubic feet.*	*Cubic feet.*	
Oak	1,600,000	2,100,000	3,700,000	18
Beech with other little hardwoods	800,000	8,300,000	9,100,000	43
Conifers	5,500,000	2,700,000	8,200,000	39

The average price per cubic foot was:

	Cents.
For timber or work wood—	
Oak	17
Beech	11
Conifers	8.5
For firewood—	
Oak	5.5
Beech	6.7
Conifers	4.2

On the whole the State received 7.2 cents per cubic foot for all its timber and firewood. Among the improvements made during the year the items of roadmaking and reforestation are most conspicuous.

In the State forests alone about 1,500 acres were seeded, generally at a cost of \$2 to \$3 per acre, the lowest being 60 cents; while in few cases the cost exceeded \$4 per acre. About 3,200 acres were planted, 1,280 acres for the first time, the rest being corrections of former failures. Planting largely with hardwoods cost on an average about \$5.50 per acre. Roadmaking is vigorously pursued, as much of the land is quite rough, and well-planned, permanent, macadamized roads have proven to be among the best investments. In some of the districts forest railways have also been constructed.

The final results during 1891 were as follows:

Income from wood	\$1,523,000
Other products	22,000
Chase	15,000
Total	1,560,000

Of this \$54,000 is figured for wood, which was given to persons holding servitude rights.

The expenses were:

Running expenses—	
Central forest bureau	\$26,000
Oberfoersters	97,000
Guards	116,000
Logging	231,000
Roadmaking	47,000
Planting, sowing, drainage, etc	47,000
Other running expenses	128,000
Permanent expenses	60,000
Total expenses	752,000
Real gross income	1,522,000
Net income	770,000

The following figures present the course of these relations for the decade ending 1891:

Financial results for the State forests in Alsace-Lorraine.

Year.	Gross income.	Cut per acre and year.		Per acre of total area.			Price of wood per cubic foot.
		Wood over 3 inches.	Total.	Gross income.	Expenses.	Net income.	
		Cubic feet.	*Cubic feet.*				*Cents.*
1882	\$1,337,000	43	55	\$3.77	\$2.20	\$1.55	6.1
1883	1,370,000	42	55	3.86	2.04	1.81	6.5
1884	1,429,000	45	61	4.03	2.04	1.97	6.2
1885	1,301,000	45	59	3.67	2.05	1.61	5.8
1886	1,284,000	45	59	3.62	2.01	1.59	5.7
1887	1,308,000	48	62	3.67	2.06	1.59	5.5
1888	1,335,000	45	57	3.74	1.98	1.74	6.0
1889	1,371,000	46	58	3.84	2.08	1.74	6.2
1890	1,477,000	49	61	4.12	2.06	2.04	6.5
1891	1,522,000	46	56	4.24	2.09	2.12	7.3

The net income, in spite of large yields in wood material and a fairly good market, is comparatively small, though slightly improving. In 1886, when this income was still lower, a special investigation was undertaken, to set forth the reasons of this small net revenue and to suggest improvement. All oberfoersters of note contributed their opinions, and on the whole good results seem to have come from their suggestions for improvement. The chief trouble evidently lies in the great proportion of hardwoods, which leads to a large production of firewood and a small proportion of timber or work wood. Thus 66 per cent of all oak, 91 per cent of all beech, and 83 per cent of all other hardwoods had to be sold as cord and fire wood, bringing generally about 5 cents per cubic foot solid, or about $5 per cord, while for the coniferous woods only 36 per cent has to be sacrificed as cord wood, the rest being sold as timber for just twice the amount obtained for firewood.

This condition of affairs is materially aggravated by the general use of coal as fuel and the rejection of beech as tie timber on railways, etc. This condition of affairs in Alsace-Lorraine is of great interest in considering the forest conditions of the United States. It shows evidently that it is the coniferous timbers which must be looked to as the important ones, and that even large supplies of hardwoods can not be expected to replace such staples as white pine or spruce.

Methods of German Forest Management.

The following brief description of the methods of German forest management, by which the results described have been attained, was originally prepared in connection with an exhibit at the World's Fair, which the chief of the Division of Forestry collected and installed upon the invitation and at the expense of the German Government, and is mainly reprinted with additions from his annual report for 1893. The description having been based upon the objects exhibited no attempt has been made to alter the form.

MAP WORK AND FOREST DISTRICTING.

The first requirement in the management of any property is that all its conditions should be known and recorded; hence a topographic survey of the forest district to be placed under management is the first requisite. Such survey refers not only to the boundaries and topographical features of the district itself, but also to the surroundings, especially with reference to connections with markets. Finally, for government forests, the geographical position of the forest areas in general should be grouped according to ownership. Maps of the latter description were exhibited from the Governments of Bavaria and of Wurttemberg.

These show in three different colors the forest areas belonging to the Government, to communities and institutions, and to private owners. From these it could be seen not only that the three classes of proprietors share about equally in the ownership of the forest area, but that the Government owns mainly the forests on the mountains, where forest management must be carried on not for profit, but for indirect benefits in the preservation of favorable soil and water conditions, which therefore makes the permanent, well-organized management "by and for the people" necessary. Contrary to the notion to which currency is so often given in the United States, the various governments of Germany do not own more than 35 per cent, exercising partial control (so as to prevent destruction and waste) over only 15 per cent in the hands of communities and institutions, and leaving the balance of 50 per cent of the forest area in private hands almost entirely without restriction.

Sometimes the contours of the country are also indicated on the maps, which serve the useful economic purpose of permitting ready reference of the forest areas to the topography. As an instance of such work there was shown a relief map of Hesse. On this the forest areas were indicated in green color.

For the sake of orderly administration, the whole country is separated into forest divisions or inspections (sometimes both), each of which forms a separate unit of administration.

It is to be understood that we are now speaking only of the Government forests, which are under a uniform general administration.

The administration of the Government forests is usually assigned either to the finance

department (as in Bavaria) or to the department of agriculture and forestry (as in Prussia), with one director and council directly in charge under the supervision of the minister or secretary. The position of the director (Oberlandforstmeister) corresponds somewhat to that of our Commissioner of the General Land Office, except that, an extensive technical knowledge being needed in the position, the incumbent is promoted through all positions from the lower grades. Again, each forest division is placed under a separate administrative body consisting of an administrator (Oberforstmeister) with a council of forest inspectors (Forstmeister), each of whom has supervision of a number of the final units of administration, the forest districts (Oberfoersterei, Forstamt). The district officer (Oberfoerster, Revierfoerster, etc.), with a number of assistants, rangers (Foerster), and guards (Schutzbeamte), is then the manager and executive officer in the forest itself, while the higher supervising and inspecting officials are located at the seats of government.

SURVEY OF THE FOREST DISTRICT.

The survey of each forest district is carried out to the utmost minutiæ.

In Prussia the maps of the districts are made on the scale of 1:5,000 in portfolio sheets, representing a careful survey by theodolite of the boundaries of the district, the permanent differences of soil and occupancy (roads, waters, fields, meadows, moors, etc.), and the division of the district into smaller units of management. This kind of map, of which only three copies are made, is then, for purposes of use in daily routine, reduced to a scale of 1:25,000 on one sheet, and printed. The first matter of interest that strikes us on these blank or base maps is the division lines by which the district is divided into parcels or compartments. In the plain these lines divide the district into regular oblong compartments (Jagen) of about 60 to 75 acres each, with sides of 100 and 200 yards, respectively, separated by openings or avenues which we may call "rides" (Gestell, Schneisse), so that the whole makes the appearance very much like the map of an American city regularly divided into blocks. The rides (from 8 to 40 rods wide) running east and west and north and south are lettered, the former, broader ones (main avenues) with capital letters, the latter (side avenues) with small letters, while the compartments are numbered. In the forest itself at each corner a monument of wood or stone indicates the letters of the rides and numbers of the compartments, rendering it easy to find one's way or direct any laborer to any place in the forest. The rides are often used as roads and serve also the purpose of checking fires, etc.

In the hill and mountain districts this regular division becomes impracticable and the lines of compartments conform to the contour, while the opening of the avenues is restricted to those which can be readily transformed into roads; roads, indeed, determining the division lines wherever practicable.

In hill or mountain districts topographic or contour maps become necessary, especially for the purpose of rational road construction, a matter on which in modern times great stress is laid and to which we shall refer later on more in detail. Such contour maps are sometimes executed in papier-maché or gypsum models for readier reference.

PRINCIPLES OF MANAGEMENT.

The fundamental principles upon which the German Government forests and most of the communal and private forests are managed is briefly expressed in the idea that the forest growth is to be treated as a crop to be reproduced as soon as harvested, involving continuity of crops. To carry this principle into effect most advantageously the management must take care to husband the natural forces and conditions upon which thrifty forest growth relies, which leads to the second principle, that of highest efficiency of crops, or the two leading principles combined, to produce the largest amounts of material (or revenue) in the shortest time without impairing the condition and capacity for reproduction of the forest, perpetuating valuable forest growth wherever this is the best crop or where soil conditions make a forest cover desirable. In government forests in addition the financial principle prevails of treating the forest as a permanently invested capital, from which only the interest is to be used, making the amount harvested or the revenue derived to be as nearly alike from year to year or from period to period, and as nearly corresponding to the annual accretion, as it is possible to make them.

The present Oberlandforstmeister, or director, of the Prussian forest department uses the following language in laying down the principles upon which the Government manages its forests:

> The Prussian State forest administration does not accede to the principles of a continuous highest soil rent based upon compound interest calculations, but believes, in contradistinction to private forest management, that it can not avoid the obligation in the management of the State forests of keeping in view the welfare of the whole community of citizens, and therein taking into consideration the need for continued supply of wood and other forest products as well as the other objects to which in so many directions the forest is subservient. The administration does not consider itself entitled to pursue a one-sided financial policy, least of all to submit the Government forests to a pure money-making management strictly based on capital and interest calculations, but considers it its duty to so manage the forests as a patrimony belonging to the whole nation that the present generation may be benefited by the highest possible usufruct in satisfying its wants and deriving the protection which the forest renders, and that to future generations may be secured at least as large usufruct of the same kind.

To carry out these principles the intimate knowledge of the conditions of the property, referred to above, is necessary and is obtained by a careful forest survey as a basis for a systematic administration and forest regulation.

These data of this forest survey are not only recorded in writing but such as can be readily noted are finally placed upon the blank maps described above, together with the results of the forest regulation described further on, so that the manager can readily overlook the details of his district and the propositions for its management.[1] This information—after further subdivision of the compartments where needed on account of differences in soil conditions or growth—is given by means of different colors, difference in shade, numbers, figures, marks, and signs. These maps, which are prepared after a most painstaking forest survey, and which we may call "manager's map" (Plate XXXII), show at a glance not only the nature of soil conditions and what the principal kind of timber and its admixtures are in each compartment or subdivision, but also how old the growth; whether it is to be treated as a coppice, standard coppice, or timber forest; at what period in the rotation it is to be cut, and such notes as the manager himself may add from year to year, as, for instance, the yearly fellings, plantings, movable nurseries, new road projects, etc.

One of the most instructive exhibits in this direction was that showing the changes in Timlitz forest, Saxony. The map of the district in 1822 presented about the condition of one of our mismanaged Michigan forests of pine and hard woods mixed, from which all the good timber had been culled, leaving it to inferior kinds with few groups of straggling pines and more valuable hard woods, without symmetry or system in the distribution of kinds or age classes. At the same time a map was constructed showing ideally how the forest was to look after eighty years' well-planned management. We can then follow in the maps made every ten or twenty years the changes in appearance under the hand of the forester. During the management new information and experience have dictated modifications of the original working plan, giving rise to a new manager's map, the approach to which appearing in the timber map for 1885 leaves no doubt that at the end of the period of regulation we will have a well-grown pine forest, with deciduous trees mixed in or confined to the more suitable situations, so disposed over the area that annually or periodically the same amount, or nearly so, of valuable material can be harvested.

The painstaking methods of surveying, describing, measuring, calculating, planning, bookkeeping, and repeated revising of all the work from decade to decade were shown in the regulation work of the district of Hinternah, Prussia, contained in six large folio volumes of manuscript, continued from the year 1822 to the last revision in 1890. We can only briefly indicate what this work involves, which was briefly summarized in the following exhibit:

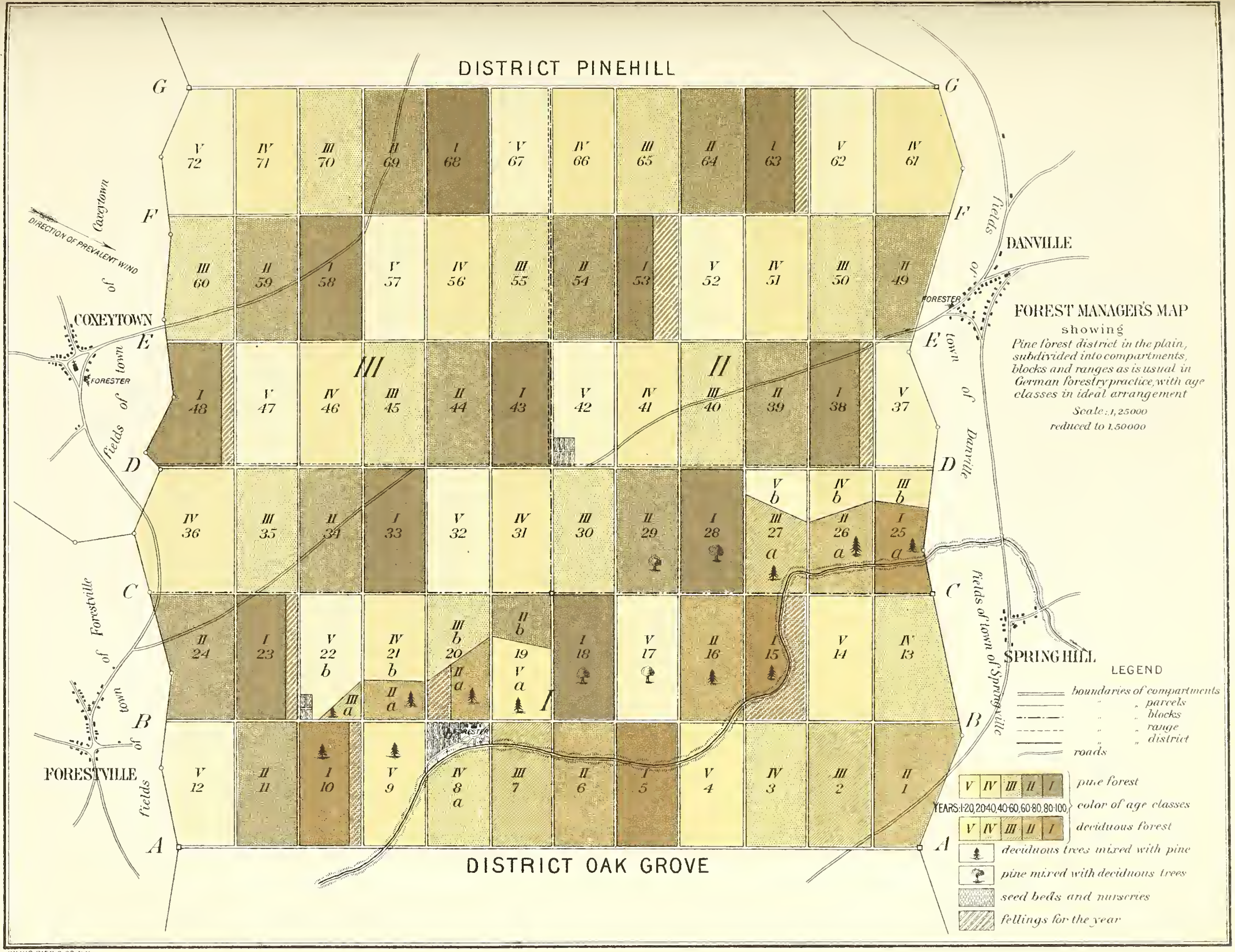
Forest Regulation.

PROGRESS OF WORK REQUIRED TO BRING FOREST AREAS UNDER RATIONAL FOREST MANAGEMENT.

I. *Geodetic and topographic survey and mapping.*

II. *Forest survey* in connection with I, noting all areas distinguished by quality of soil, composition, and age of timber; general description of forest conditions, of climatic conditions, of surrounding conditions, of possible dangers, of market conditions, means of transportation, etc.

[1] Each State government pursues somewhat different methods of mapping. Sometimes two sets of maps are made, one to show the conditions, which might then be called a timber map, the other to show the working plan; but these are now mostly combined into one.



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III. *Forest districting.* Division of forest into parcels or lots and aggregation of lots into blocks and ranges. In the plain, rectangular lots, divided by cleared lines called rides (Gestell), are customary; in hilly and mountainous country division lines follow the configuration of soil. Differences of soil or character of growth within lots give rise to formation of sublots.

IV. *Forest yield valuation* (assessment). Ascertaining amounts of timber standing, rate of growth on various sites, determining capability of production and future yield in material and money.

V. *Determining plan of management* (working plans). General plan for all time; special plans for period of ten to twenty years. Determining length of rotation; amounts annually to be cut, designating lots to be cut, with a view to obtaining favorable distribution of age classes; thinnings to be made; methods to be used in felling and cultures.

METHODS OF FOREST REGULATION.

In Prussia it was Frederick the Great who first ordered a regulated administration of the Government forests soon after the beginning of his reign. The first simple prescriptions of dividing the forests into equal areas and cutting every year a proportionate area were followed up with more elaborate ordinances, having in view a closer equalization of the amounts of material harvested and revenues obtained, besides other considerations of management for continuity, until finally the basis for present methods of regulation was reached in the ordinance of 1836, since modified in its details, under which "the preservation, revision, and perfection of the work of forest valuation and regulation" is carried on.

The modus operandi, similar in principle in all Government forest administrations, is about as follows:

Let us assume that the Government has purchased[1] a new forest district, comprising, say, 10,000 acres, the average size of the existing districts. The necessary surveys and blank maps, as explained, have been made and the boundaries carefully established in the field, the division into compartments or parcels, larger or smaller according to the need of a more or less intensive management, have been noted on the maps and marked on the ground (the avenues perhaps partially opened), and for the sake of satisfactory administration a number of the parcels have been combined into subdistricts, "blocks," or ranges; and thus the first—purely geometrical—basis for a rational administration has been established. Now the arithmetical basis is to be ascertained. For this, in the first place, a general description of the district in its present condition is desirable, parts of which, however, can be furnished only after the more thorough measurements described later. Such a description recites all needful knowledge regarding the extent, the manner of division, the boundaries, and the legal rights. Next follows a description in general terms of topography, climate, and soil conditions, and of the forest growth, being a condensation of the special description by parcels. The manner of treatment hitherto, the market conditions, current market prices, and usual wages are noted. Then, after recital of the processes and methods by which the information in the following detail work has been obtained, the principles adopted for the management and its motivation are stated, forming a general guide for the manager for all time.

These principles are formulated by a commission after sufficient general knowledge of the condition of the district is obtained. In this important part of the general description not only the territorial partition of the district into compartments and blocks or ranges is determined, and reasons given for it, but also the system of management for each block or parts of blocks, whether

[1] Prices for forest soil vary, of course, according to their location and condition, just as in our country. In 1849 Bavaria sold 27,000 acres of her State forests at $68 per acre. In Prussia the Government has lately (1881–1887) paid prices ranging from $5 to $60 per acre, and for a round 70,000 acres the price per acre was $21 average. These were mostly devastated waste lands in the northern plain. In Thuringia, where prices for wood and land are higher, the price for forest land is from $20 to $60 and as high as $80. These prices do not, of course, include any timber growth, the value of which, if present, is calculated according to well-known careful methods of determining "expectation values." According to a calculation by Dr. J. Lehr, based on the net income as representing interest at a 3 per cent rate, and assuming a ninety-year rotation of the forest growth for the entire German Empire, the forest land was worth $25 per acre and the wood on it $156 per acre.

coppice, standard coppice, timber forest, etc.,[1] and the length of rotation—i. e., the time within which a block is to be cut over and reproduced; furthermore, the principles according to which the fellings are to progress, reproduction is to be secured, thinnings are to be made, the annual yield to be expected, and the time within which the forest is to be brought into a regular systematic order of management—in short, all the general framework of the management as far as determining a set policy into which the special working plans should fit. Before this report can be made final, however, the work of the valuator or examiner must have proceeded to some extent.

VALUATION WORK.

The valuator or estimator, upon whose work as a basis the general and special working plans depend, begins by examining and describing briefly the conditions of the soil, its productive capacity, and the kind and appearance of the growth in each compartment (or subparcel, if conditions of growth or soil make such subdivision desirable). In the description the dominating kind of timber, or, if mixed in equal proportions, that upon which the management is to be promi-

[1] NOTE.—Timber forest (Hochwald, high forest) is a forest in which trees are allowed to grow to maturity, and reproduction is effected either by natural seeding from the old growth in various ways, or by planting or sowing after removal of the old growth; it is usually managed in rotations of 70 to 120 years.

Coppice (Niederwald, low forest) is a forest in which reproduction is expected by sprouts from the stumps; this is usually managed in rotations of 10 to 40 years.

Standard coppice (Mittelwald, middle forest) is a combination of the two former, the standards being allowed to grow to maturity and reproduction being secured both by seed and sprouting.

Determining the rotation.—Our friends who are attempting to bring about a more rational treatment of our forests have often a mistaken notion as to when timber should be cut, when it is ready for the harvest. This can not be determined by any set period, as in the ripening of fruit in agriculture, or by any more or less defined age, much less by any diameter measure. The determination of the "felling age" (Haubarkeitsalter) or of the length of "rotation" (Umtrieb) depends on the use to which the crop is to be put, the manner in which it is to be reproduced, and the amount of material that can be produced, or the amount of profit that can be derived from it. This determination is one of the most difficult, requiring both careful financial calculation and knowledge of forest technique.

The "silvicultural rotation" is that which considers mainly the forest technique, being the time when perfect natural reproduction is most surely attainable—i. e., fullest seed production in timber forest, highest sprouting capacity in coppice forest; or when preservation of the productive capacity of the soil, avoidance of damage from windfalls, diseases, etc., are uppermost considerations. These considerations of course also influence in part the determination of any of the following rotations, which we may call "economic rotations."

The "rotation of greatest material production" is that which allows the forest to grow as long as the average annual accretion is at a maximum. This differs of course with species, climate, soil, etc. If for the mass of material we substitute its money value and strive to so arrange that the time of rotation coincides with the largest money returns, we have a "financial rotation."

Various points of view lead to different kinds of financial rotations:

"Rotation of the highest harvest value," or "technical rotation," which attempts to produce certain desired sizes and qualities in largest quantity with a view of obtaining thereby the largest money return for the crop under the circumstances (management for telegraph poles, fence posts, osier holts, tan-oak coppice).

"Rotation of the highest forest revenue," when the growth is to be harvested at the time of its maximum average annual net money value; this time is influenced both by the amount of material and the price paid for better sizes and quality of wood. In this rotation no regard is paid to the original capital invested in the soil; when this latter factor is introduced into the calculation we arrive at the true "financial rotation" or "rotation of the highest soil (or ground) rent," in which the forest is to be cut at a time when the capital invested in soil, stock, and management furnishes the highest interest rate. This capital, as far as the soil is concerned, may be represented by its actual cost or by its market value, or else by its capacity for production (Bodenerwartungswerth; soil-expectation value), which is found by adding the values of expected returns at harvest discounted to the present time and deducting the expenses incurred up to the time of harvest, similarly discounted.

To determine this value experience tables must give the data. Local conditions and prices and the rate of interest applied of course influence the length of the financial rotation. It is shortest for a firewood management (in Germany, say 60 to 70 years), for spruce and pine at an interest rate of 2 to 3 per cent a rotation of 70 to 90 years, with oak 120 years, appear as profitable rotations; where small sizes, mining timber, posts, poles, etc., are bringing good prices, the most profitable financial rotation may be shorter. It stands to reason that the length of this rotation, as well as of all others, can be only approximately calculated. The forestry literature of Germany is most prolific just now with regard to determining financial rotations, and the highest mathematical skill is employed in the discussion.

Growth (Bestand, stand) is here and further on used in the collective sense of the word to denote an aggregate of trees, for which also the word "stand" may be employed.

nently based, is named first, and the average age of the growth with special reference to the dominating timber is ascertained for the purpose of ranging the parcel into an "age class," which comprises usually twenty years, so that the growth of 1 to 20, 21 to 40, 41 to 60 years, etc., form each an age class or period. The density of the growth and larger openings devoid of tree growth are specially noted. The valuator at the same time is expected to form, from general appearances, an opinion as to the best treatment of each parcel in the near future, and note it, and especially whether the growth is to be cut during an earlier or later period than its age would warrant, considering the likelihood of its thrifty or its unsatisfactory growth. He also estimates the amounts to be taken out in thinnings for the next twenty years.

With this information established a table may be constructed, in which the area of each parcel is entered, according to its average age or "age class," modified by considerations of productive capacity, and from this a "timber map" is made, showing the present conditions of the forest, the kind of dominating timber in each parcel being denoted by a color, intermixed timbers by signs, and the age by the shade of the color in 4, 5, or 6 gradations, according to the number of age classes, as shown in the accompanying ideal map.

ARRANGEMENT OF AGE CLASSES.

Now follows the determination of the future arrangement of age classes, the object of which is to have, when the forest is regulated, in each period of the rotation an approximately equal or equally producing area to be cut. It therefore becomes necessary to shift the distribution of age classes, in order to attain the equality of the sum of areas in each period. In addition to the mere equalization of areas, there are several other considerations guiding the valuator in arranging the age classes. The oldest timber, as well as that which for some reason has ceased to make satisfactory growth, is of course to be cut first; hence the conditions of these areas are more specially examined regarding health, density of cover, soil, vigor, etc. In coniferous growths, especially in the plain, the danger from windfalls, if one parcel is cut and thereby the other exposed to the prevailing storms, necessitates such an arrangement in the location of the fellings (or age classes) that the removal of an old growth will leave behind it a young growth which is less liable to be thrown. This local distribution of the age classes by which, in the direction of the prevailing winds, no two neighboring growths are assigned to the same period is also desirable from other considerations. By avoiding a series of extensive fellings side by side the danger from fires is lessened and liability to spread of diseases and insect attacks, danger from frost, and drought to young growths is confined or reduced. Hence an arrangement of the age classes as near as possible after the following scheme has been generally adopted, in which the Roman figures denote the age classes, I standing for the oldest growth, containing, if the rotation has been set at 100 years, timber of 80 to 100 years, to be felled within the first twenty years; II for that to be felled within twenty-one to forty years from the present, and so on; V to be felled in from eighty to one hundred years.

	V	III	I	IV
	IV	II	V	III
Prevailing winds→	III	I	IV	II
	II	V	III	I

FIG. 23.—Diagram showing arrangement of age classes.

In mountainous districts, where the topography influences the expense of transportation, fellings are often more concentrated and the higher parcels used and reproduced before the lower, in order to avoid injury to the young growth by a reversed condition when the material from above would have to pass through the young growth below. Various minor points may also dictate exceptional arrangement. In coppice growth, needed protection of the stocks against cold north

winds makes it desirable to have the fellings progress from the south and west toward north and east. Altogether it will have become apparent that the distribution of successive fellings is an important matter, not only from the standpoint of regulated administration, but also of successful culture.

In the accompanying map (Pl. XXXII) we have attempted to give an idea of the matter on which a "manager's map" is constructed, and how ideally in a forest of the plain the arrangement of age classes would appear when the forest regulation is perfected.

YIELD CALCULATIONS.

When the distribution of areas has been effected in accordance with the considerations set forth, the yield calculations are made. These are computed after careful measurements and by various methods of calculation, which have been developed after much experience during more than one hundred years.

Since the different compartments are cut at different times, not only the present "stock on

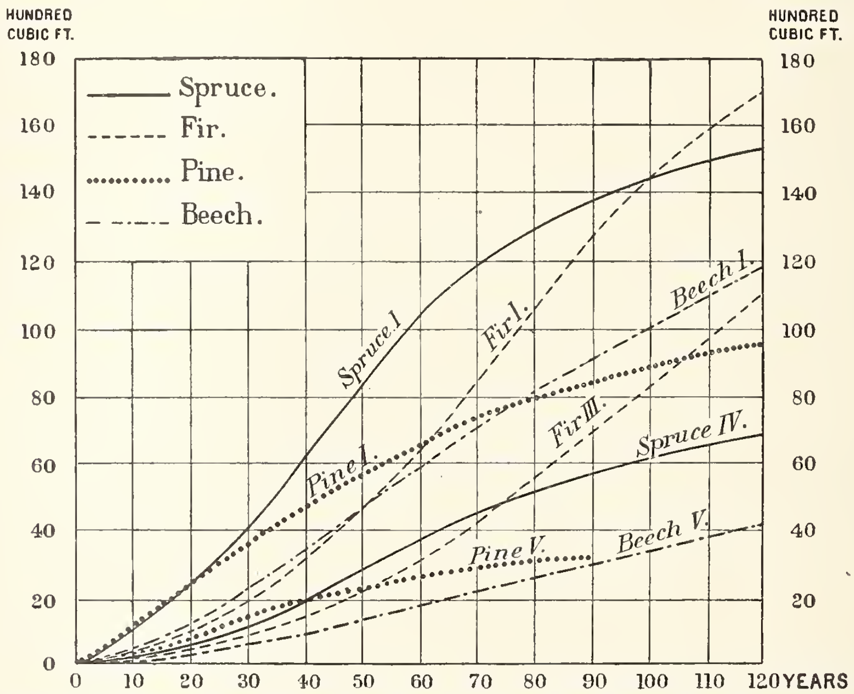


FIG. 24.—Diagram showing comparative progress of yields of spruce, fir, pine, and beech on best and poorest site classes.

hand" needs to be measured, but also the accretion for each age class from the present to the middle of the period in which it is to be utilized as to total quantity (decreasing in arithmetical proportion as the stock on hand is diminished by fellings), when by adding the two quantities and dividing the total by the number of years in the rotation or time of regulation the equalized yearly quota to be utilized, or "felling budget" (Haubarkeitsertrag or etat), can be calculated.

The determination of existing stock is made by measuring diameter breast high by means of calipers, estimating the average height, and calculating contents with the aid of tables which give the corresponding volumes of timber wood (above 3 inches diameter). These tables are constructed after numberless detail measurements, from which the "factor of shape" for each species, soil, or climate is derived, for, since the tree is neither a cylinder nor a cone, which could be calculated from the base and height, the modification from either of these two forms, the "factor of shape" must be determined experimentally in order to arrive at the approximately true contents. In very irregular growths and with skillful valuators a simple estimating of contents or the use of so-called normal yield or "experience tables," which give for the various species, soils, and climates the amount of wood that would normally be produced per acre at a given period, is not excluded.

Normal yield table for spruce.

[Main growth (exclusive of thinnings) per acre.]

Age.	Number of trees.	Cross-section area of all trees breast high.	Average height.	Wood above 3 inches diameter.	Wood, total mass.	Age.	Number of trees.	Cross-section area of all trees breast high.	Average height.	Wood above 3 inches diameter.	Wood, total mass.
Site class I.						*Site class III.*					
		Sq. ft.	*Feet.*	*Cu. ft.*	*Cu. ft.*			*Sq. ft.*	*Feet.*	*Cu. ft.*	*Cu. ft.*
10 years	....	49.2	4.9	86	715	10 years	....	18.3	1.9	....	200
20 years	2,591	114.4	16.7	1,101	2,174	20 years	....	53.7	6.6	100	772
30 years	1,700	159.5	29.2	2,603	4,204	30 years	3,732	86.6	15.7	472	1,617
40 years	1,065	188.4	47.6	4,748	6,378	40 years	2,412	130.1	25.6	1,244	2,760
50 years	724	209.7	62.6	7,222	8,623	50 years	1,580	154.9	36.7	2,574	4,247
60 years	515	225.8	76.7	9,209	10,625	60 years	1,056	171.8	48.2	4,004	5,634
70 years	390	237.1	88.2	10,582	12,198	70 years	724	185.3	59.0	5,219	6,893
80 years	321	244.9	97.4	11,655	13,213	80 years	500	196.2	67.9	6,220	7,994
90 years	269	250.9	105.3	12,555	14,043	90 years	424	205.2	74.1	7,093	8,866
100 years	243	258.4	112.5	13,299	14,715	100 years	380	214.9	79.4	7,922	9,638
110 years	229	264.5	117.7	13,971	15,272	110 years	346	223.2	88.0	8,694	10,296
120 years	226	269.7	121.4	14,586	15.730	120 years	320	230.6	85.6	9,324	10,725
Site class II.						*Site class IV.*					
10 years	....	26.1	3.2	....	415	10 years	....	11.3	1.6	....	157
20 years	....	77.9	11.5	315	1,201	20 years	....	36.5	4.6	....	500
30 years	2,364	89.9	22.6	1,187	2,460	30 years	....	72.2	10.5	140	1,044
40 years	1,619	151.8	35.1	2,502	4,018	40 years	3,164	107.9	18.0	515	1,830
50 years	1,161	180.1	47.2	4,176	5,791	50 years	1,968	130.1	26.2	1,287	2,788
60 years	842	200.1	59.7	6,220	7,851	60 years	1,276	143.5	35.1	2,231	3,761
70 years	639	213.6	71.8	7,808	9,481	70 years	864	154.9	42.6	3,089	4,519
80 years	484	222.7	83.0	9,295	10,725	80 years	648	162.6	51.5	3,790	5,248
90 years	356	231.3	91.5	10,339	11,683	90 years	554	172.3	57.1	4,361	5,763
100 years	301	239.2	97.7	11,125	12,398	100 years	500	181.5	61.3	4,848	6,249
110 years	293	246.5	103.0	11,740	13,013	110 years	464	187.0	63.3	5,305	6,707
120 years	291	252.3	106.6	12,269	13,585	120 years	....	191.4	66.6	5,720	7,150

In very regular growths trial areas only are measured. The more usual manner of determining the rate of accretion, however, for purposes of yield calculation, is by felling sample trees of each class, dissecting and measuring the accretions of past periods.

In modern times the exact measurements are mostly confined to the growths that are utilized during the first or first two periods of twenty years.

FELLING BUDGET.

After all these data for each compartment have been booked, and the yield of branchwood and roots—for even these are mostly utilized—as well as the probable amounts to be taken out in thinnings, have been estimated and recorded, and after the likelihood of decreased accretion in the different compartments has also been determined from measurements and experience, the "felling budget" is determined as a sum of the stock on hand and the amount of annual accretion multiplied by the time, during which it is allowed to grow, i. e., in the average to the middle of the period in which the compartment is placed, divided by the period of rotation. Thus a growth of eighty-five years, which showed a stock on hand of 3,825 cubic feet per acre, and hence had an average accretion hitherto of $3{,}825 \div 85 = 45$ cubic feet per year, which is likely to be reduced on account of gradual reduction in stock and other untoward conditions to 30 cubic feet, would yield during the first period $3{,}825 + 30 \times 10 = 4{,}125$ cubic feet. And if the compartment contained 50 acres it should be credited in the working plan in the column for the period I with $4{,}125 \times 50 = 206{,}250$ cubic feet. By adding up the amounts of the yield of all the compartments placed in the first period and dividing by 20 (the length of the period) the annual budget which should be felled during the period is found. If, however, it is desired to equalize the fellings more or less through a longer period— for instance, the time of rotation—then the amounts in all the periods must be summed up, and these sums as nearly as possible equalized by shifting the position of the compartments from one period into another (necessitating always new calculations of the accretion) until the equalization in the periodic sums is effected.

Even then, however, before finally determining the annual budget, a calculation is made to see whether the area contains as much timber as it normally should; if more, the budget may be increased; if less, a saving must be made in order to bring up the stock on hand to the normal. If, for instance, we know from the experience tables that our forest should normally yield 50 cubic feet per acre a year in a 100-year rotation, then the normal stock would be $100 \times 50 \div 2 = 2{,}500$ cubic

feet per acre. This is the average amount of wood per acre which we should strive to keep in stock in order to get the full benefit of the productive capacity of the soil and insure an equal growth and equal annual cut for all time. In reality this ideal is, of course, never reached, but this so-called normal forest, conceived in ideal condition, serves as a guide in the working plans, and the conception is a most useful and important one. To put it into practice we must either save at first on the annual cut until normal condition is attained, or we may increase the cut if more old timber than necessary for normal stock is on the ground. Additional reserves may also be provided for to avoid any unforeseen shortcomings in the budget due to insect ravages, mistakes in calculations, etc.

We can not here enter into the details of all the work of the valuator, being satisfied with having indicated in general the methods pursued. In coppice management, of course, all these fine calculations become unnecessary, and the periodical or annual cut is determined by area mainly.

From the general plan thus elaborated the special plan for the first period or half period of the management is worked out in detail both for fellings, cultures, and other work, road building, drainage, etc. This special plan, then, is the basis on which the local manager finally makes out the annual plans of work, which are submitted for revision and approval to the controlling officers. Thus, while the general and special working plans lay down the general principles, the annual plans, into which enter considerations of immediate needs and financial adjustments, permit such deviations from the general plans as may appear needful from year to year. Every ten or twelve years, or at other stated periods, a careful revision of the whole regulation work is made, in which the carefully noted experiences of the manager are utilized to correct and perfect the plans.

FOREST PROTECTION.

In this country the greatest danger to the forest, besides the indiscriminate cutting, is to be found in fires. How little this scourge of American forests is known in Germany may appear from the statistics of fires in the Government forests of Prussia (representing 60 per cent of the German forest area), 56 per cent of which are coniferous, which show that railroading may be carried on without the necessity of extra risks, if proper precautions are provided. During the years 1882–1891 there had occurred 156 larger conflagrations—96 from negligence, 53 from ill will, 3 from lightning, and only 4 from locomotives. Seven years out of ten are without any record of fire due to this last cause.

From 1884 to 1887 fires occurred in Prussia on 3,100 acres, but only 1,450 were wholly destroyed, i. e., 380 acres per year, or 0.005 per cent of the total area of Government forests. In Bavaria during the years 1877–1881 only 0.007 per cent of the forest area was damaged by fire, and the loss represented only 0.02 per cent of the forest revenues. During the unusually hot and dry summer of 1892 only 49 fires, damaging more or less 5,000 acres, occurred.

Besides the thorough police organization and the compartment system, which permits not only ready patrolling but also ready control of any fire, the system of safety strips, described in the report of this division for 1892, where a fuller discussion of this subject may be found, prevents the spread of fire from locomotives.

A much more fruitful cause of damage to the cultivated forests of Germany is found in insect ravages. The annual expenditures in fighting and preventing these in the Prussian Government forests in ordinary times amount to about $50,000. Caterpillars and beetles eat the leaves, and thereby reduce the amount of wood produced and the vitality of the tree; bark beetles follow and kill it; borers of all kinds injure the timber. Hence entomology, the study of life habits of the injurious insects and the methods of checking their increase, forms part of the forester's work.

Fungus growth and decay kill the standing tree and injure the cut timber. The study and methods of counteracting this injury form, therefore, part of the work of the forester.

FOREST CROP PRODUCTION OR SILVICULTURE.

While we have so far considered mainly the administrative and managerial features of German forestry practice, we come now to the most important and truly technical branch of the art, namely, the forest crop production or forest culture. This part we may call forestry proper, for while the methods of forest regulation, forest utilization, and forest protection, which may be

comprised in the one name, "forest economics," are incidental, and may differ even in principle in various countries and conditions, the methods of crop production or forest culture, being based on the natural laws of the interrelations of plants to soil and climate, must, at least in principle, be alike all over the world. Here pure forestry science finds its application and development.

These principles have been elucidated more fully in the next chapter. We will, therefore, here only briefly restate the more important ones with some of their applications in German practice.

PLANTING.

Seemingly the simplest and easiest way of reproducing the crop is that practiced in agriculture, namely, removing the entire mature crop and sowing or planting a new crop. But this method, which has been so largely practiced in Europe and admired by our countrymen and writers on forestry, has its great drawbacks, which have of late become more and more apparent, and the tendency now is to return more and more to the "natural reproduction." While the simplicity of the method of clearing and planting recommends itself for a routine or stereotype management, it has not always proved as successful as would be expected. The large clearings which the young planted seedlings are unable to protect from the drying influences of sun and

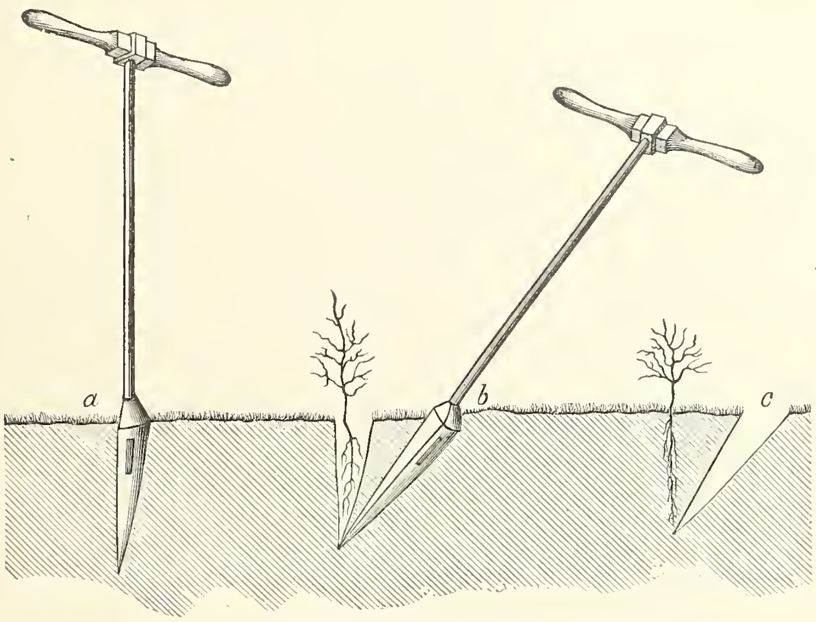


FIG. 25.—Iron dibble used in setting out small pine seedlings.

wind bring about a desiccation and deterioration of the forest soil and an enormous increase of insect pests, while other dangers in later life from wind and disease have been largely the result of these uniform growths. And when it is understood that to secure a desirable stand the plantings must be gone over and fail places replanted five, six, and more times, it becomes apparent that the method is extremely expensive, and hence the proper treatment of the natural crop with a view to its reproduction by natural seeding is the most important part of forest culture. Yet under certain conditions, and where no natural crop to manage is found, planting or sowing becomes a necessity, and various methods and tools have been developed to meet various conditions.

It would exceed the limits of this report to describe these various methods; we can refer to only one of the simplest and cheapest with which every year many millions of small 1 or 2 year old pine seedlings are set out in soils which do not need or do not admit of preparation by plow or spade. The instrument used is an iron dibble (fig. 25); the shoe, with one rounded and one flat side, in shape like a half cone, 8 inches long with $3\frac{1}{2}$-inch base; the handle, a five-eighths-inch rod, $3\frac{1}{2}$ feet long, is screwed into the base of the shoe and carries a wooden crossbar, by which the instrument is handled. The modus operandi is to thrust this iron dibble into the ground; then by moving it lightly back and forth to somewhat enlarge the hole and withdraw it; a boy or girl

puts the plantlet in the hole to the flat side; the dibble is thrust again into the ground 1 to 1½ inches back of the first hole somewhat slantingly toward the bottom, and pressed forward to fasten the plant in its stand; then by irregular thrusts the last-made hole is obliterated. Two planters with a boy, carrying the plants in a mixture of loam and water to keep the roots moist and also heavy for better dropping, may set 5,000 plants in a day.

INTRODUCTION OF EXOTICS—WHITE PINE YIELDS.

The valuable species of trees indigenous to Germany which are subject to special consideration in forest management are but few. The most important forest-forming ones are 1 pine, 1 spruce, 1 fir, 1 larch, 1 oak, 1 beech, 1 alder. In addition we find of broad-leaved trees a blue beech, 1 ash, 3 kinds each of elm, maple, and poplar, in some parts a chestnut, and 2 kinds of birch and linden, and several willows, together with some 8 or 10 kinds of minor importance, while of conifers in certain regions 4 other species of pines are found. Some years ago the attention of European foresters was forcibly turned to the richness of the American forest flora, and a movement set in to introduce exotic tree species which might be more productive or show better qualities than the native. Our white pine, a good-sized section of which was exhibited, had been quite extensively planted in the beginning of this century, and these plantations, some 80 or 90 years old, are now coming into use. The quality of the wood, however, has not as yet found much favor, but the quantity per acre exceeds that of any of the native species. Records are extant which show, at 70 years of age, a yield of 14,000 cubic feet of wood containing about 70,000 feet of lumber B. M. per acre.

On moderately good forest soil in Saxony a stand 78 years old contained over 400 trees per acre, of which three-fourths were white pine, the rest spruce, larch, beech, and oak. Only 5 white pine trees were under 70 feet high, the majority over 80. Notwithstanding the crowded position, only 45 trees were under 8 inches diameter, the majority over 12 inches, the best 28 inches. The total yield was 12,880 cubic feet of wood per acre, besides the proceeds of previous thinnings. The rate of annual accretion in cubic feet of wood for white pine in the last years amounted to 2.5 per cent of the total contents of the trees, or about 0.4 cubic foot per tree. Of the trunk wood at least 90 per cent could be utilized for lumber, since the shape of these trunks was so nearly cylindrical as to be equal in contents to one-half a perfect cylinder of the height and diameter of the trees taken breast high.

A stand 82 years old on poor land produced 12,500 cubic feet of wood, indicating an average yield for the eighty-two years of 212 cubic feet of wood per annum, of which about 700 feet of lumber B. M. could be calculated. On very poor soil and planted very thick without admixture of hard woods it produced trees 24 feet high and 5 inches thick in twenty years; and on fairly good soil trees 54 feet high, 11½ inches thick, in thirty to thirty-five years, excelling in either case the native spruce (*P. excelsa*) both in height and thickness.

It is also of interest to mention in this connection that a plantation of about 7 acres in the city forest of Frankfort-on-the-Main during the eighteen years ending 1881 brought $115 rent per year for the privilege of seed collecting alone; failing to produce seed only three out of the eighteen years and yielding a maximum of $500 rent during one of the eighteen years; much of the seed finding a market in the United States.

Besides the white pine, the black locust has also for quite a long time found a home in the plantations of Europe, but the species which are now propagated in large quantities, having after trial shown superior advantages in behavior and growth, are our Pacific coast conifers, the Sitka spruce, the Douglas spruce, the Lawsons cypress, and the Port Orford cedar, sections and photographs of which, grown in Germany, were exhibited, as well as of black walnut and hickory. These trees are now used to plant into fail places or openings, in groups or single individuals, and are especially prized for their soil-improving qualities and their rapid growth.

The methods of management for natural reproduction are generally divided into three classes, namely, the coppice, when reproduction is expected from the stumps; the standard coppice, when part of the growth consists of sprouts from the stump and another part of seedling trees; and the timber or high forest, when trees are grown to maturity and, unless harvested and replanted, reproduction is effected entirely by natural sowing.

COPPICE MANAGEMENT.

This practice is employed for the production of firewood, tanbark, charcoal, and wood of small dimensions, and is mostly applicable only to deciduous trees. The capacity of reproduction from the stump is possessed by different species in different degrees, and depends also on climate and soil; shallow soil produces weaker but more numerous shoots than a deep, rich soil, and a mild climate is most favorable to a continuance of the reproductive power. With most trees this capacity decreases after the period of greatest height-growth; they should therefore be cut before the thirtieth year, in order not to exhaust the stock too much. The oak coppices for tan bark are managed in a rotation of from ten to twenty years. Regard to the preservation of reproductivity makes it necessary to avoid cutting during heavy frost, to make a smooth cut without severing the bark from the stem, and to make it as low as possible, thus reducing liability to injuries of the stump and inducing the formation of independent roots by the sprouts.

It will be found often that on poor and shallow soil trees will cease to thrive, their tops dying. In such cases it is a wise policy to cut them down, thus getting new, thrifty shoots, for which the larger root system of the old tree can more readily provide. This practice may also be resorted to in order to get a quick, straight growth, as sprouts grow more rapidly than seedlings, the increased proportion of root to the part above ground giving more favorable conditions of food supply. It must not be forgotten, however, that this advantage has to be compensated somewhere else by a disadvantage; sprouts, though growing fast in their youth, cease to grow in height at a comparatively early period, and for the production of long timber such practice would be detrimental.

Regard to the preservation of favorable soil conditions, which suffer by oft-repeated clearing, requires the planting of new stocks where old ones have failed. Mixed growth, as everywhere, gives the best result. Oaks, walnut, hickory, chestnut, elm, maples, birch, cherry, linden, catalpa, and the locust also, with its root-sprouting habit, can be used for such purpose.

If when cutting off the sprouts, at the age of from 10 to 20 years, some trees are left to grow to larger size, thus combining the coppice with timber forest, a management results which the Germans call "Mittelwald," and which we may call standard coppice management.

STANDARD COPPICE.

This is the method of management which in our country deserves most attention by farmers, especially in the Western prairie States, where the production of firewood and timber of small dimensions is of first importance, while the timber forest, for the production of larger and stronger timbers, can alone satisfy the lumber market. The advantages of this method of management, combining those of the coppice and of the timber forest, are:

(1) A larger yield of wood per acre in a short time.
(2) A better quality of wood.
(3) A production of wood of valuable and various dimensions in the shortest time with hardly any additional cost.
(4) The possibility of giving closer attention to the growth and requirements of single individuals and of each species.
(5) A ready and certain reproduction.
(6) The possibility of collecting or using for reforestation, in addition to the coppice stocks, the seeds of the standards.

The objections to this mode of treatment are the production of branches on the standards when freed from surrounding growth, and the fact that the standards act more or less injuriously on the underwood which they overtop.

The first objection can be overcome to a certain extent by pruning, and the second by proper selection and adjustment of coppice wood and standards. The selection of standards—which preferably should be seedlings, as coppice shoots are more likely to deteriorate in later life—must be not only from such species as by isolation will grow into more useful timber, but if possible from those which have thin foliage, thus causing the least injury by their cover to the underwood. The latter should, of course, be taken from those kinds that will best endure shade. Oaks, ashes, maples, locust, honey locust, larch, bald cypress, a few birches, and perhaps an occasional aspen, answer well for the standards; the selection for such should naturally be from the best-grown

straight trees. The number of standards to be held over for timber depends upon the species and upon the amount of undergrowth which the forester desires to secure. The shadier and the more numerous the standards the more will the growth of the coppice be suppressed. From a first plantation one would naturally be inclined to reserve and hold over all the well-grown valuable saplings. The coppice is, of course, treated as described above.

As before mentioned, on account of the free enjoyment of light which the standards have they not only develop larger diameters, but also furnish quicker-grown wood (which in deciduous trees is usually the best) and bear seed earlier, by which the reproduction of the forest from the stump is supplemented and assisted. Any failing plantation of mixed growth, consisting of trees capable of reproduction by coppice, may be recuperated by cutting the larger part back to the stump and reserving only the most promising trees for standards.

If equally well grown coppice and standards are desired, a regular distribution of the standards, mostly of the light-needing, thin-foliaged kinds, should be made. If prominence is given to the production of useful sizes, the standards may be held over in groups and in regularly distributed specimens, in which case those of the shade-enduring kinds are best in groups.

THE TIMBER FOREST.

In the timber-forest management we may note various methods: The method of selection (Plenterwald), in accordance with which only trees of certain size are cut throughout the whole forest, and the openings are expected to fill up with an after-growth sown by the remaining trees. This method prevailed in former ages, but was finally almost everywhere abandoned because of the difficulty of organized administration and control of such an irregular forest containing trees of all ages, and because the after-growth is apt to progress but slowly with fore-grown trees surrounding and overshadowing it, or may consist of worthless kinds. Of late a revival of this method with various modifications designed to meet the objections is noticeable; the advantage of keeping the soil constantly shaded and thereby preserving the soil moisture also recommending this method. More uniform growths, more regular distribution of age classes, and a more regulated administration was possible by various "regeneration methods," by which a certain area—a compartment—would be taken in hand and the cutting so systematically directed that not only a uniform young growth would spring up through the whole compartment, but by the gradual removal of the mother trees light would be given to the young growth as needed for its best development. This method (Femelschlag) is practiced almost exclusively in the extensive beech forests, somewhat in the following manner:

REGENERATION METHODS.

In the first place it is necessary to know the period at which a full seed year may be expected. This differs according to locality and kind. One or more years before such a seed year is expected the hitherto dense crown cover is broken by a preparatory cutting of the inferior timber, enough being taken out to let in some light, or rather warm sunshine, which favors a fuller development of seed, the increased circulation of air and light at the same time hastening the decomposition of the leaf-mold and thus forming an acceptable seed bed.

As soon as the seed has dropped to the soil, and perhaps, in the case of acorns and nuts, been covered by allowing pigs to run where it has fallen, a second cutting takes place uniformly over the area to be regenerated, in order that the seeds may have the best chance for germination—air, moisture, and heat to some degree being necessary—and that the seedlings may have a proper enjoyment of light for their best development and yet not be exposed too much to the hot rays of the sun, which, by producing too rapid evaporation and drying up the needful soil moisture, would endanger the tender seedlings. This cutting requires the nicest adjustment, according to the state of the soil, climatic conditions, and the requirements of seedlings of different kinds.

While the beech requires the darkest shade, the pine tribe and the oaks demand more light, and should, by the successive cuttings, be early freed from the shade of the mother trees. Beech seedlings are more tender, and only by the gradual removal (often protracted through many years) of the shelter of the parent trees can they be accustomed to shift for themselves without

liability of being killed by frost. The final cutting of the former generation of trees leaves many thousand little seedlings closely covering the soil with a dense shade.

That the method of management must differ according to species and local conditions is evident; and in a mixed forest especially are the best skill and judgment of the forester required to insure favorable conditions for each kind to be reproduced. It is to be expected that such seedlings are rarely satisfactory over the whole area, and that bare places of too large extent must be artificially sown or planted.

Another method is the "management in echelons" (Coulissen, Saumschlag), which consists in making the clearings in strips, and awaiting the seeding of the clearing from the neighboring growth. It is applicable to species with light seeds, which the wind can carry over the area to be seeded, such as larches, firs, spruces, most pines, etc.

The cuttings are made as much as possible in an oblong shape, with the longest side at right angles to the direction of the prevailing winds. The breadth of the clearing, on which occasional reserves of not too spreading crowns may be left, depends of course on the distance to which the wind can easily carry the seed which is to cover the cleared area. Observation and experience will determine the distance. In Germany, for spruce and pine, this has been found to be twice the height of the tree; for larch, five or six times the height; for fir, not more than one shaft's length. From 200 to 360 feet is perhaps the range over which seeding may be thus expected. One year rarely suffices to cover the cleared area with young growth, and it takes longer in proportion to the breadth of the cutting. This method is very much less certain in its forestal results than the next named, and more often requires the helping hand of the planter to fill out bare places left uncovered by the natural seeding. But it is the one that seems to interfere least with our present habits of lumbering, and with it eventually the first elements of forestry may be introduced into lumbering operations.

To be sure, it requires from three to eight times the area usually brought under operation, but instead of going over the whole area every year it may be operated in a number of small camps systematically placed along a central road connecting the different camps or cuttings with the mill.

As a rule the pine forests in Germany are reproduced by artificial plantations, the spruce forests by either natural or artificial regeneration, or both combined, while the beech forests are entirely reproduced as described above, oaks and other hard woods being usually planted, although a return to a more extended use of natural reproduction is noticeable.

IMPROVEMENT CUTTINGS—THINNINGS.

The principles which underlie the practice of thinning out young growths in order to accelerate their development have been theoretically well developed, but the practice in Germany remains behind the theory. The difficulty of disposing of the material taken out in the thinnings discourages the practitioner, and the financial value of the operation in the acceleration of the remaining crop is not fully appreciated.

A few results of German practice in thinning may serve to give an indication of its value.

A natural growth of pine (Scotch) which was thinned when six years old showed an increased rate of accretion three times as great as that of the part not thinned, which was also deficient in height growth.

A 50-year-old spruce (Norway) growth, having been twice thinned, showed an average accretion 22 per cent greater than the part not thinned.

A growth of spruce (natural sowing), slightly mixed with maple, aspen, willow, and ironwood, when 15 years old was opened to the poor population to take out firewood; thus one-half of the growth for a few years was thinned out irregularly. The part thus thinned eighteen years later contained four and one-half times more wood than the undisturbed part; the former contained trees of from 1 to 9 inches in diameter and 15 to 65 feet in height; the latter did not produce any above 5 inches in diameter and 48 feet in height.

Another experiment, made upon a pine growth 50 years old, showed that by interlucation the rate of growth within eleven years stood three to one and three-fourths in favor of the thinned part.

Another writer planted Scotch pine 6 feet apart; two years later he planted the same ground

to bring the stand to 3 feet apart; he thinned when fifteen years old, and carefully measured contents when twenty years old. Although the plantation was stocked on poor soil, yet the average annual accretion was found to be 2.43 cords (Austrian) per acre, a yield "which is unexcelled." The writer adds that "if in such growths the number of trees is reduced in the fifteenth to twentieth years to 280 trees per acre, the yield in sixty years might equal that obtained in one hundred or one hundred and fifty years in the old manner."

A plantation of Norway spruce, made with seed, was when thirty-three years old still so dense that it was impenetrable; hardly any increase was noticeable and the trees were covered with lichens. When thirty-five years old it was thinned, and again, when forty-two years old the condition of the growth was such as to make a thinning appear desirable; between the two thinnings, within seven years, the accretion had increased by 160 per cent, or 27 per cent yearly in the average, and the appearance of the trees had changed for the better.

A coppice of tanbark oak was thinned when fifteen years old on half the area; when twenty years old both parts were cut, and it was found that the thinned part yielded more wood and more and better bark than the unthinned part, and yielded in money 14.5 per cent more, although no higher price was asked for the better bark.

An area of 12 acres was planted, one-half with 2-year-old pine seedlings from the forest, the other half with seed.

Three thinnings were made with the following yield of round firewood (cut to billet length and over $2\frac{3}{4}$ inches in diameter) and brushwood (less than $2\frac{3}{4}$ inches in diameter).

The planted part yielded at the thinnings:

When—	Firewood.	Brush.
	Cords.	*Cords.*
10 years old	1.4	1.4
15 years old	4.9	2.8
18 years old	4.5	2.8
Total	10.8	7

The sowing was first thinned when 8 years old, yielding:

When—	Firewood.	Brush.
	Cords.	*Cords.*
8 years old	....	2.8
10 years old	....	3.6
20 years old	3.2	1.4
Total	3.2	7.8

In twenty-four years the total yield, inclusive of thinning, was:

	Cubic feet of solid wood.
Planted part	3,495
Sowed part	1,998
In favor of planted part	1,497

Thinnings are usually made for the following purposes:

(1) Improvement cuttings, to improve the composition of the forest and give advantage to the better kinds.

(2) Interlucations, to improve the form and hasten development of young timber.

(3) Regeneration cuttings, to produce favorable conditions for seed formation and reproduction of the forest.

(4) Accretion cuttings, to improve rate of diameter growth in older timber.

Thinnings are to open the crown-cover, giving access to light and air, their object being to accelerate decomposition of the litter and turn it into available plant food; to improve the form and hasten the development of the remaining growth. The degree of thinning depends on soil, species, and age, and is best determined as a proportion between the present growth and that which is to remain with reference either to crown-cover, mass, or diameter.

Since it is observed that in the struggle for existence among the individual trees there are quite early some trees getting the advantage and becoming dominant, it is inferred that thinnings are most effective in the earlier period of the crop.

In discussing the degree to which the thinning is to be made, a classification of the trees according to the character of their development is made by German foresters as follows:

Dominant or superior growth.	*Class 1.*—Predominant trees with highly developed crowns. *Class 2.*—Codominant trees with tolerably well developed crowns. *Class 3.*—Subdominant trees with normal crowns, but poorly developed and crowded above.
Dominated or inferior growth.	*Class 4.*—Dominated trees with crowns poorly developed and crowded laterally. (*a*) Crowns wedged in laterally, yet not overtopped. (*b*) Crowns compressed, partly overtopped. *Class 5.*—Suppressed trees, entirely overtopped. (*a*) Crowns still having vitality (shade enduring species). (*b*) Crowns dying or dead.

The following illustration of the appearance of these tree classes will be found serviceable in understanding these relations.

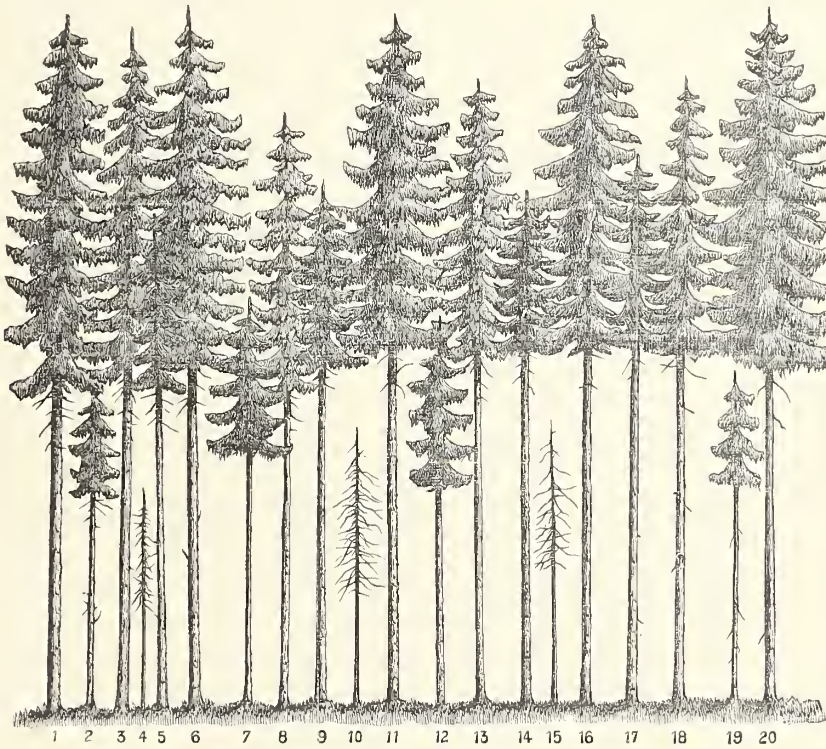


FIG. 26.—Tree classes: Classification according to crown development. Schematic. Class 1 (predominant): Nos. 1, 3, 6, 11, 16, 20; class 2 (codominant): Nos. 8, 13, 18; class 3 (subdominant): Nos. 9, 14, 17; class 4 (oppressed): Nos. 5, 7, 12; class 5 (suppressed, *a*): Nos. 2, 19; class 5 (suppressed, *b*): Nos. 4, 10, 15.

The degrees of thinning usually resorted to are the following:

(1) Slight thinning takes out trees of class 5.

(2) Moderate thinning takes out trees of class 5 and 4*b*.

(3) Severe thinning takes out trees of class 5, 4, and sometimes 3.

The time when the first thinning should take place is generally determined by the possibility of marketing the extracted material at a price which will cover at least the expense of the operation. This is, however, not always possible, and the consideration of the increase in value of the remaining growth, or rather of the detriment to the same by omission of timely thinning, may then be conclusive.

On good soil and on mild exposures interlucation may take place earliest, because here the growth is rankest and a difference in the development of the different stems is soonest noticeable.

Light-needing and quicker-growing kinds show similar conditions to those grown on good soil, and here, therefore, early thinnings are desirable. In these cases the thinnings have also to be repeated oftenest, especially during the period of prevalent height accretion. Absolute rules as to the time for interlucations and their periodical repetition evidently can not be given. The peculiar conditions of each individual case alone can determine this. The golden rule, however, is early, often, moderately. The right time for the beginning of these regular and periodical interlucations is generally considered to have arrived when the natural thinning out before mentioned commences and shows the need of the operation. This occurs generally when the crop has attained the size of hop poles. At this stage the well-marked difference in size of the suppressed trees will point them out as having to fall, and there will not be much risk of making any gross mistakes. Until the trees have attained their full height the thinning should remain moderate. From this time forward it will prove expedient to open out the stock more freely without ever going so far as to thin severely. Within the last few years new and revolutionary ideas regarding principles and methods to prevail in thinnings are gaining ground, which we have not space here to discuss.

UNDER-PLANTING.

All these manipulations experience modifications according to circumstances, different species and soil conditions requiring different treatment. One of the most interesting modifications, the results of which in a given district were fully exhibited, is the v. Seebach management in beech forests. Such a management, which contemplates the production of heavier timber in the shortest time, tries to take advantage of the increase in accretion due to an increase of light which is secured by severe thinning, and in order to prevent the drying out of the soil by such severe thinning a cover of some shady kind is established by sowing or planting. This cover gradually dies off under the shade of the old timber, the crowns closing again after a number of years. The rate of growth in a stand of 70 to 80 years was thereby increased from 51 cubic feet per acre and year to 77 cubic feet per acre and year, while a neighboring stand, otherwise the same but not so treated, increased by only 60 cubic feet, distributed over a larger number of trees.

The same method is applied to the production of heavy oak timber. In this case the oak growth is thinned out when about 60 years old and "underplanted" with beech. It may also be applied to older growths with advantage, as appears from the following results:

A stand of oaks 150 to 160 years old in 1846 was thinned to 96 trees per acre, averaging 37 cubic feet of wood per tree, the cleared space being "underplanted" with beech and spruce. In 1887 the oaks, now 190 to 200 years old, of which 59 trees only were left, contained 56 cubic feet in the average, thus growing during the last forty years more than one-half as much as during the one hundred and fifty to one hundred and sixty years previous to the operation, i. e., doubling the rate of growth. In this case, under the light-foliaged oaks, some of the beech and spruce developed sufficiently to furnish marketable material.

With Scotch pine it has been found in one case that while the average accretion of a stand 120 years old under ordinary condition was about 59 cubic feet per acre and year—the yield by thinning included—a stand underplanted with beech showed an accretion of 100 cubic feet per acre and year, besides much better log sizes and earlier supply of saw timber.

Translated into money an example from Bavaria may be cited as follows:

On 1 acre of pine 80 years old, underplanted at a cost of $2.85 per acre with beech now 40 years old, there were found—

	Yield of wood.	Average annual accretion per acre.
	Cubic ft.	*Cubic ft.*
105 pines	322	40
2,300 beech	156	39
Total	478	79

Supposing this stand to be left forty years longer, it may be figured that the pine would bring $650 and the beech $120; total per acre, $770, of which $49 was yielded in thinnings. White pine without undergrowings is expected to produce only $520 per acre when 120 years old.

FORESTERS, FORESTRY EDUCATION, AND FORESTRY LITERATURE.

To be sure, the highly elaborate system of forest administration and forest management here outlined could not be developed or maintained without a special high-grade education of those who direct the work. This education is provided for in the most ample manner, and consists not only in theoretical studies at schools, academics, and universities, but also in practical studies in the forest itself under the guidance of competent and experienced forest managers.

The course which applicants for positions in the higher administrative forestry service are expected to follow, with more or less modification in the different states, may be briefly outlined here:

After promotion from college the student goes into the woods for a short period (one-half to one year) to acquaint himself, under the guidance of a district manager, with the general features of the business he proposes to engage in, and thereby tests his probable fitness for it. He then visits for two and one-half or three years a forestry school (called academy when by itself, when at a university it is connected with the "faculty" for national economy), where theoretical studies with demonstrations in the forest are pursued.

After examination and promotion the applicant is bound at his own expense to occupy himself for two years at least in studying the practice in various districts, changing from place to place. If occupation can be found for him he is employed at small daily wages on some scientific or administrative work, always keeping an official diary of his doings and observations, certified to by the district manager with whom he stays, and which forms part of his final examination. For nine months during this time he must continuously perform all the duties of a lower official—a ranger—for a whole or part of a range, and sometimes also for a given time certain functions of a district manager. Then, after two years of law studies at a university, he enters into a close and difficult examination for a position as district manager, lasting eight to ten days. By passing this he is placed on the list of eligibles, and has thereby secured a right, enforcible in the courts if need be, to a position when a vacancy arises and his name is reached in the order of the list. This, in Prussia, may now be within eight or ten years after listing. During the interval he may be, and mostly is, employed on daily wages in various sorts of scientific and administrative work, such as revising and making new valuations, laying out roads, acting as tutor at the academies or as assistant to district managers, or else taking the place of a manager temporarily, etc.

The higher administrative offices are filled by selections from the managers, length of service counting only when special fitness for the kind of work required accompanies it; so that, as in the army, the highest officer has been through all the grades below, and is conversant with every detail of the service. The pay is small, graded in each kind of position according to length of service and somewhat according to the cost of living in different places. The honor of the position, to which usually other honors are added, its permanency, and the assurance of a pension, graded according to length of service, in case of disability or age, make up for small salaries. The salaries, subject to change from time to time, without adding the value of perquisites like houses, farm lands, etc., range about as follows in Prussia:

1 director (Oberlandforstmeister)		$3,600
4 forest councilors (Landforstmeister)	$1,800 to	2,400
33 chief inspectors (Oberforstmeister) (with additions for house and traveling up to $1,100)	1,050	1,500
89 inspectors (Forstmeister) (with additions for house and traveling up to $1,100)	900	1,500
679 district managers (Oberfoerster) (with additions up to $825 and house and field)	500	900
3,390 rangers (Foerster) (with house and additions up to $110)	260	360
349 guards (Waldwaerter)	100	200

The rangers (Foerster) follow different courses of instruction, part of which they receive in subordinate positions under district managers; while serving in the army in special battalions (chasseurs) they receive also theoretical instruction, which is supplemented in special schools. When finally promoted to the responsible position of rangers, in which much discretion and latitude are given them, their pay amounts to from $260 to $360, with a house and field, with the assurance of pension on withdrawal.

The following schools are provided for the higher grades of foresters:

Higher forestry schools in Germany for the education of forest managers.

[Austria and Switzerland included.]

Name of place.	State.	When founded.	Length of course (years).	Instructors of forestry branches proper.	Total number of instructors.	Average attendance of forestry students.
At universities:						
Giessen	Hesse	1825	3	3	(a)	40-50
Tübingen	Wurttemberg	1818	(b)	3	(a)	50-60
Munich	Bavaria	1878	(b)	8	a 18	c 90-100
At polytechnicum:						
Karlsruhe	Baden	1832	3	2	19	15-30
Zürich	Switzerland	1855	3	3	a 20	15-30
Vienna	Austria	1875	3	6	43	130-140
Separate academies:						
Aschaffenburg	Bavaria	1807	2	2	9	90-100
Tharandt	Saxony	1811	2½	3	10	100-135
Eisenach	Saxe Weimar	1830	2	3	8	65-75
Eberswalde	Prussia	1831	2½	6	14	140-150
Münden	do	1868	2½	5	13	40-60

a The entire corps of professors of the university. In Munich 18 professors are engaged in lecturing on subjects which concern forestry students; in Zürich, 20 professors. In Munich all studies can be followed in any year, as the students may select. The attendance varies, of course, widely in different years, having been as high as 216 in Eberswalde and 120 in Münden. The above figures are for 1885-86.

b Not prescribed.

c During the winter of 1898 there were 140 students at Munich out of 527 forestry students at all forestry schools.

The following table will serve to give an idea of what instruction is to be had at these institutions:

Plan of studies at Forest Academy Eberswalde.

Subjects of instruction.	Whole number of hours.	Subjects of instruction.	Whole number of hours.
FUNDAMENTAL SCIENCES.		PRINCIPAL SCIENCES.	
Natural sciences.		Cultivation of forests	80
		Forest implements	20
General and theoretic chemistry	32	Geographical forest botany	48
Special inorganic and organic chemistry applied	80	Protection of forests	32
Physics and meteorology	80	Forest usufruct and technology	80
Mineralogy and geognosy	60	Forest surveying	20
Definition of minerals and rocks	20	Appraising forests	80
Reviews for organic natural sciences	16	Calculation of the value of forests and forest statistics	32
Botany in general and forest botany in particular	64	Administration of forest and hunting	48
Anatomy of plants, vegetable physiology and pathology	60	Redemption of rights of usage	32
Microscopy	20	Forest history	40
Botanical reviews	20	Forest statistics	20
Botanical excursions, each 2½ hours	80	Review of various forest matters	56
General zoology	16	Examinations	40
Vertebrates	80	Forest excursions, each 4 hours	352
Invertebrates, with special reference to forest insects	80		
Zoological preparations	16	Total	980
Zoological reviews	20		
Zoological excursions, each 3 hours	96	SECONDARY SCIENCES.	
Total natural sciences	840	*Jurisprudence.*	
Mathematics.		Civil law	72
		Criminal law	32
Geodesy	72	Civil and criminal lawsuits and constitutional rights	40
Interest and rent account	20	Jurisprudence	36
Wood-measuring	20		
Mathematical reviews and exercises	56	Total	180
Surveying and leveling exercises, each 4 hours	192	Construction of roads	32
Plan-drawing exercises, 2½ hours	80	Hunting	32
		Shooting exercises, 2 hours each	96
Total mathematics	440		
Economic sciences.		Total sum of hours for secondary sciences	340
		Grand total	2,648
Public economy and finances	48		
Total sum of hours for fundamental sciences	1,328		

	Per cent.
Fundamental sciences	50
Principal sciences	37
Secondary sciences	13

Average per instruction week (21 weeks in winter, 17 during summer; 2 winter courses, 3 summer courses):

$$\frac{2648}{93} = 28.5 \text{ hours, or per day, 4.9 hours.}$$

If we were to codify into a system the science of forestry as developed in Germany we might come to the following scheme, which exhibits the various branches in which a well-educated forester must be versed:

System of Forestry Knowledge.

I. Forest policy—economic basis of forestry (the condition).

Aspects.

1. *Forestry statistics.* (Areas, forest conditions; products. By-products: Trade; supply and demand; prices; substitutes.)
2. *Forestry economics.*
   (a. Study of relation of forests on climate, soil, water, health, ethics, etc.
   b. Study of commercial peculiarities and position of forests, and forestry in political economy.)
3. *History of forestry.*

Application.

4. *Forestry politics.* (Formulation of rights and duties of the State and of its methods in developing forestry; legislation, State forest administration, education.)

II. Forest production—technical basis of forestry (the crop).

Aspects.

5. *Forest botany.* (Systematic botany of arborescent flora; forest geography; plant and climate; biology of trees in their individual and aggregate life; forest weeds.
6. *Soil physics and soil chemistry* with special reference to forest growth.
7. *Timber physics.* (Anatomy of woods; chemical physiology and physical properties of woods. Influences determining same; diseases and faults.)
8. *Technology.* (Application of wood in the arts; requirements and behavior; mechanical and working properties; durability; special needs of consumers; use of by-products, waste materials, minor forest products.)

Application.

9. *Silviculture.* (Methods of growing the crop.)
   a. Natural reforestation; cutting for reproduction.
   b. Artificial afforestation; procurement of plant material; nursery practice, choice of plant material, methods of soil preparation, of forest planting.
   c. Improving and accelerating the crop. Cultivation, filling, thinning, pruning, undergrowing.
   d. Systems of management. Timber forest, standard coppice, coppice, etc.
10. *Forest protection.* (Against insects, climatic injuries, fire, cattle, etc.)
11. *Forest improvement and engineering.* (Treatment of denuded mountain slopes, shifting sands, barrens, swamp and moors, road building, etc.)
12. *Forest utilization.* (Methods of harvesting, transporting, preparation for market.)

III. Forest organization—administrative and financial basis (the revenue).

Aspects.

13. *Forest survey.* Ascertaining area and condition of the forest; ascertaining rate of accretion, yield.
14. *Forest valuation and statics.* Ascertaining money value of forest soil and forest growth as capital of the management and comparing financial results of various kinds of management.

Application.

15. *Forest regulation.* Establishing units of management and administration; determining working plans, distributing yearly or periodical cut, etc.
16. *Forest administration.* Routine methods, business practice, personnel, organization of service and mechanical operations.

LITERATURE.

In addition to the live teachings, which an able corps of professors impart at these institutions and that which competent managers are ready to impart to the young students in the forest itself, a large number of weekly, monthly, quarterly, and annual journals and publications are keeping the foresters and forestry students *au courant* with the progress of forestry science and forestry technique. Adding the publications of this nature which appear in Austria and Switzerland in the German language, and which have their constituency in Germany as well, we can make the

following respectable list, not counting the journals of the lumber trade and other related publications. Those marked with an asterisk (*) are to be found in the library of the Division of Forestry; those marked (†) are considered the best or are most comprehensive; those marked (?) have been discontinued.

German forestry periodicals.

Name of publication.	Published at—	Issued—	Established.
Allgemeine Forst-u. Jagdzeitung * †	Frankfort on the Main	Monthly	1824
Aus dem Walde	Hanover	Irregularly	1865
Aus dem Walde	Frankfort on the Main	Weekly	(?)
Deutsche Forst-u. Jagdzeitung	do	Semimonthly	(?)
Forstliche Blaetter	Berlin	Monthly	1863
Forstlich-naturwissenschaftliche Zeitschrift * †	Munich	do	1892
Forstwissenschaftliches Centralblatt * †	Berlin	do	1856
Jahresbericht des schlesischen Forstvereins	Breslau	Annually	1841
Jahresbericht der preussischen F. u. J. Gesetzbegung	Berlin	do	1868
Land-u. Forst-wirthschaftliche Zeitschrift	Vienna	Quarterly	1886
Muendener forstliche Hefte *	Berlin	Irregularly	1892
Oesterreichische Forst zeitung *	Vienna	Weekly	1882
Der praktische Forstwirt fuer die Schweiz	Davos	(?)	(?)
Schweizer Zeitschrift fuer Forstwesen	Zürich	Quarterly	(?)
Tharandter forstliches Jahrbuch *	Dresden	Annually	1850
Verhandlungen der Forstvereine	Various	do	
Bericht ueber die Versammlung deutscher Forstmaenner	do	do	
Zeitschrift fuer Forst-u. Jagdwesen * †	Berlin	Monthly	1869
Zentralblatt fuer das gesammte Forstwesen * †	Vienna	do	1875
Zeitschrift der deutschen Forstbeamten	(?)	(?)	(?)

Should the reader wish to collect a library of the most modern thought on any or all subjects pertaining to forestry in Germany the list of books contained in the library of the Department of Agriculture, a catalogue of which has been published, with over 1,200 numbers and probably 2,000 volumes, would give him a good selection.

FORESTRY ASSOCIATIONS.

Forestry associations thrive better in Germany than in the United States and are of a different character; they are associations of foresters, who practice what they preach. There is no more need of a propaganda for forestry than there would be here for agriculture, and the discussions, therefore, are moving in technical, scientific, and economic directions. Besides some thirty or forty larger and smaller local associations, there is held every year a forestry congress, at which the leading foresters discuss important questions of the day.

FOREST EXPERIMENT STATIONS.

In addition to all these means of education and of advancement of forestry science, and in addition to the demonstration forests connected with the various schools of forestry, there has been developed in the last twenty years a new and most important factor in the shape of forest experiment stations, which are also mostly connected with the forestry schools. If forestry had a strong and well-supported constituency before, this additional force has imparted new impulses in every direction.

The first incentive for the establishment of these stations came from the recognition that the study of forest influences upon climate could be carried on only with the aid of long-continued observations at certain stations. Accordingly, during the years 1862 to 1867, forest meteorological stations were instituted in Bavaria, which, under the efficient direction of the well-known and eminent Dr. Ebermayer, for the first time attempted to solve these and other climatic questions on a scientific basis. The results of these and other observations have been fully discussed in Bulletin 7 of the Forestry Division and are briefly recorded in this report.

While these stations were continued and others added in all parts of the country, an enlargement of the programme was soon discussed with great vigor, leading (between the years 1870–1876) to the institution of fully organized experiment stations in Prussia, Bavaria, Saxony, Thuringia, Wurtemberg, Baden, Switzerland and Austria following in the same direction; all of these finally combining into an "association of German forest experiment stations," similar to the association of agricultural experiment stations in our country. Thus the science of forestry, which hitherto had been developed empirically, has been placed upon the basis of exact scientific investigation, the fruit of which is just beginning to ripen in many branches.

We in the United States are fortunate, in that we can learn from the experience and profit from the assiduous work of these careful investigators. While we may never adopt the admirable administrative methods that fit the economic, social, and political conditions of Germany, we shall ever follow them where the recognition and utilization of natural laws lead to the practical acknowledgment of general principles and to desired economic results in forest culture.

Forest Management in British India.

In order to show how the transfer of German methods may work advantageously, even in a country entirely differently conditioned, the results obtained by the forest management in British India are here briefly stated.

India, with a total area of nearly 1,500,000 square miles or 936,000,000 acres (an area about one-half that of the United States without Alaska), has a population of about 270,000,000, or four times as great as that of the United States.

Of the entire area about 950,000 square miles, or 63 per cent, are under British rule, the remaining 550,000 square miles, with a population of about 53,000,000, being divided among a large number of more or less independent native States.

Of the entire population about 70 per cent are farmers and farm laborers, who cultivate about 200,000,000 acres of land, 30,000,000 of which is irrigated. The greater part of the main peninsula is a high plateau with steep descents to the ocean, both on the western and eastern coast.

To the north of this plateau is a broad, fertile, river plain extending from the upper Bramahputra to the mouth of the Indus, a distance of nearly 2,000 miles, without rising more than 900 feet above sea level. North of this large and densely settled Indo-Gangetic plain, and forming the barrier between India and Thibet, is the great Himalaya Mountain system, drained by the three great river systems of northern India.

More than half of India lies within the Tropics and over 90 per cent is farther south than New Orleans, the latitude of which is 30°. From this it is apparent that the climate is generally hot, but, owing to diversity of elevation and peculiarities of the distribution of rainfall, it is by no means uniform.

The rains of India depend on extraordinary sea winds, or "monsoons," and their distribution is regulated by the topography of land and the relative position of any districts with regard to the mountains and the vapor-laden air currents. Thus excessive rainfall characterizes the coast line along the Arabian Sea to about latitude 20° N., and still more the coast of Lower Burmah, and to a lesser extent also the delta of the Ganges and the southern slope of the Himalayas. A moderately humid climate, if gauged by annual rainfall, prevails over the plateau occupying the large peninsula and the Lower Ganges Valley, while a rainfall of less than 15 inches occurs over the arid regions of the Lower Indus. In keeping with this great diversity of climate, both as to temperature and humidity, there is great variation in the character and development of the forest cover. The natural differences in this forest cover are emphasized by the action of man, who for many centuries has waged war against the forest, clearing it permanently or temporarily for agricultural purposes or else merely burning it over to improve grazing facilities or for purposes of the chase. Thus only about 25 per cent of the entire area of India is covered by woods, not over 20 per cent being under cultivation, leaving about 55 per cent either natural desert, waste, or grazing lands. The great forests of India are in Burmah; extensive woods clothe the foothills of the Himalayas and are scattered in smaller bodies throughout the more humid portions of the country, while the dry northwestern territories are practically treeless wastes. In this way large areas of densely settled districts are so completely void of forest that millions of people regularly burn cow dung as fuel, while equally large districts are still impenetrable, wild woods, where, for want of market, it hardly pays to cut even the best of timbers.

The great mass of forests of India are stocked with hardwoods (i. e., not conifers); which in these tropical countries are largely evergreens, or nearly so, and only a small portion of the forest area is covered by conifers, both pine and cedar, these pine forests being generally restricted to higher altitudes. The hardwoods, most of which in India truly deserve this name, belong to a great variety of plant families, some of the most important being the Leguminosæ, Verbenaceæ, Dipterocarpeæ, Combretaceæ, Rubiaceæ, Ebenaceæ, Euphorbiaceæ, Myrtaceæ, and others, and

but a relatively small portion of them represent the Cupuliferæ and other important hardwood timber families so characteristic of our woods.

In the greater part of India the hardwood forest consists not of a few species, as with us, but is made up of a great variety of trees unlike in their habit, their growth, and their product, and if our hardwoods offer on this account considerable difficulties to profitable exploitation, the case is far more complicated in India. In addition to the large variety of timber trees there is a multitude of shrubs, twining and climbing plants, and in most forest districts also a dense undergrowth of giant grasses (bamboos), attaining a height of 30 to 120 feet. These bamboos, valuable as they are in many ways, prevent often for years the growth of any seedling tree, and thus form a serious obstacle to the regeneration of valuable timber. The growth of timber is generally quite rapid; the bamboos make large, useful stems in a single season. Teak grows into large-size saw timber in fifty to sixty years. But in spite of their rapid growth and the large areas now in forest capable of reforestation, India is not likely to—at least within reasonable time—raise more timber than it needs. In most parts of India the use of ordinary soft woods, such as pine, seems very restricted, for only durable woods, those resisting both fungi and insects (of which the white ants are specially destructive), can be employed in the more permanent structures, and are therefore acceptable in all Indian markets.

At present teak is the most important hardwood timber, while the deodar (a true cedar) is the most extensively used conifer. Teak occurs in all moist regions of India except the mountain countries, never makes forests by itself (pure forests), grows mixed with other kinds, single, or in clumps, is girdled two to three years before felling, is generally logged in a primitive way, commonly hewn in the woods and shipped—usually floated—as timber, round or hewn, and rarely sawn to size. Teak is as heavy and strong as good hickory, has little sapwood, stands well after seasoning, and is remarkably proof against decay and the still more dreaded white ants, and is really the only important export timber of India, about $2,500,000 worth having been shipped in 1894–95, bringing about $1 per cubic foot, or more than four times as much as good pine timber in the market.

As will be seen from the following figures timber forms only about 20 per cent of the export of forest products, which consist chiefly of lac, the basis of shellac (really the product of an insect) and of tanning materials:

Exports of forest products from India, 1894–95.

Lac (basis of shellac)	$7,000,000
Teak	2,800,000
Myrobalans	2,300,000
Cutch and gambier	1,450,000
Caoutchouc	550,000
Fancy woods—sandal, ebony, rosewood	290,000
Cardamoms	140,000
Total	14,530,000

The imports of timber into India have so far been very insignificant. Attempts at introducing American coniferous timber (pine, spruce, larch, and hemlock) from the Pacific coast have not been successful, though it would seem that some wood goods, such as boxes, sash and door, and cheap furniture, should find a favorable and extensive market if once the trade is established. Perhaps a treatment of these materials with some of the new fireproofing substances could be made to render them at the same time more resistant to white ants and other insect borers, and thus procure for them several important advantages at once.

In the past the people of India, as far as known, never realized the importance of their forests. They were cleared, destroyed, mutilated at all times and in all places, and the use of wood never seems to have formed an important factor in Hindoo civilization.

With the advent of foreign commerce the exploitation of the forests for the more valuable export timbers received a new stimulus and the forests were culled regardless of the future, either of forest or people. This matter was aggravated by the construction of railways, which, in themselves large consumers, also offered a premium on all that contributed to increased traffic. When, finally, it was noticed that the demands of timber for public works in some localities could

no longer be supplied without costly transportation, the matter at last received public attention. In 1856, Dr. D. Brandis was appointed superintendent of forests for Pegu; in 1862 he was charged with the duty of organizing a forest department for all India, and in 1864 he was appointed the first inspector-general for the forests of India. During the thirty-four years of its existence this department has steadily and rapidly grown in the area managed, the number of men employed, and the revenue derived for the State. In 1894–95 this forestry department had control of about 112,900 square miles of forest, nearly half of all the forests, and about 12 per cent of the entire area of India. Of these State forests, 74,000 square miles are "reserve" or permanent State forests, while the rest are held as "protected" and "unclassed," a large portion of which will become reserve or permanent forests as fast as the necessary surveys and settlement can be made.

With the irregular distribution of forests, the peculiarities of Indian affairs, and the unsurveyed wild, and difficult conditions of the forests themselves, it is but natural that the work thus far has been chiefly one of organization, survey, and protection, and to a far less degree an attempt at improvement both by judicious cutting and reforestation.

Over 33,000 square miles have been surveyed for forest purposes since 1874, and over 4,000 square miles were added during the year 1894–95, at a cost of over $200,000.

Work of establishing and maintaining boundary lines, which is often a very difficult and costly matter in the dense tropical jungles, involved during the same year an expense of over $40,000, and there are at present about 60,000 miles of such boundary lines maintained. Besides this survey work proper, there is a large force constantly at work to ascertain the amount and condition of timber supplies and to prepare suitable plans for their exploitation and improvement, so that about 12 per cent of the entire forest area, or over 570,000 acres, is by this time managed with definite working plans as to amount of timber to be cut, what areas to be thinned, reforested, etc. The work of protection is chiefly one of preventing and fighting fires. This protection with present means can not be carried on over the entire forest areas, of which large tracts are not even crossed by a footpath, and in a land where the regular firing of the woods has become the custom of centuries, and where, in addition, intensely hot and dry weather, together with a most luxuriant growth of giant grasses, render these jungle fires practically unmanageable. In all forests near settlements the forest must be isolated by broad "fire traces" or otherwise. In the jungle forests these traces must be broad; the grass, often taller than an elephant, must be cut and burned before the grass on either side is dry enough to burn. Similarly, the traces in the long-leaf pine forests must be very wide and first converted into grass strips, cut or kept clean by burning. In spite of the unusual difficulties there were in 1894–95 over 33,000 square miles protected against fire, and on only 8 per cent of this area did the element succeed in doing any damage. In this work, too, great progress has been made during the last twenty years; the efficiency has steadily increased, and the expense, about $10 per square mile in 1883, has been reduced to less than half.

In the protection against unlawful felling or timber stealing and grazing, the Government of India has shown itself fully equal to the occasion by a liberal policy of supplying villagers in proximity to the forests with fuel, etc., at reduced prices or gratis. Over $2,000,000 worth was thus disposed of in 1894–95, the incentive to timber stealing being thereby materially reduced. A reasonable and just permit system of grazing, where again the needs of the neighboring villagers are most carefully considered, not only brings the Government a yearly revenue of nearly $800,000, but enables the people to graze about 3,000,000 head of animals in the State forests without doing any material damage to tree growth.

Though the forests of India are now, and will continue for some time to be, little more than wild woods, with some protection and a reasonable system of exploitation, in place of a mere robbing or culling system, yet the work of actually improving the forests steadily increases in amount and perfection.

In the large teak forests of Burma, as well as other provinces, care is had in helping this valuable timber to propagate itself; the useless kinds of trees are girdled, huge climbers are cut off, and a steady war is waged against all species detrimental to teak regeneration. Where the teak has entirely disappeared, even planting is resorted to. Thus in Burma over 35,000 acres have been restocked with teak by means of taungyas, or plantations, where the native is allowed to burn down a piece of woods, use it for a few years as field (though it is never really cleared) on condition of planting it with teak, being paid a certain sum for every hundred trees in a thrifty

condition at the time of giving up his land. Similarly, the department has expended large sums in establishing forests in parts of the arid regions of Beluchistan, and on the whole has expended about $150,000 during 1894–95 on cultural operations, which up to that time involved about 76,000 acres of regular plantations and 36,000 acres taungyas (mostly teak), making a total of 112,000 acres, besides numerous large areas where the work consisted merely in aiding natural reproduction.

In disposing of its timber the Government of India employs various methods. In some of the forest districts the people merely pay a small tax and get out of the woods what and as much as they need. In other cases the logger merely pays for what he removes, the amount he fells being neither limited in quantity nor quality. The prevalent systems, however, are the permit system, where a permit is issued indicating the amount to be cut and the price to be paid for the same, and the contract system, where the work is more or less under control of government officers and the material remains government property until paid for. To a limited extent the State carries on its own timber exploitation, as appears from the following figures, where the cut for 1894–95 for the entire country is given:

Kind and quantity of product.	Removed by—	
	State.	Purchaser.
Timber (1,000 cubic feet)	5,700	39,900
Fuel (1,000 cubic feet)	28,000	69,000
Bamboos (1,000 pieces)	1,600	132,200
Minor products ($1,000)	90	1,500

In spite of the many difficulties, a poor market (no market at all for a large number of woods), wild, unsurveyed, and practically unknown woodlands, requiring unusual and costly methods of organization and protection, the forestry department has succeeded, without curtailing the timber output of India, in so regulating forest exploitation as to insure not only a permanence in the output, but also to improve the woodlands by favoring the valuable species, and thus prepare for an increase of output for the future, and at the same time has yielded the Government a steadily growing revenue, which bids fair to rank before long among the important sources of income.

The growth of both gross and net revenue is illustrated by the following figures:

Yearly income during the period—	Gross income.	Expenses.	Proportion of expense to income.
			Per cent.
1870–1874	$2,810,000	$1,960,000	70
1875–1879	3,330,000	2,288,000	69
1880–1884	4,408,000	2,806,000	64
1885–1889	5,834,000	3,713,000	64
1890–1894	7,974,000	4,266,000	54

From this it is clear that in India as in Europe not only the gross but also the net income has become greater in proportion as a better organization is permitted to expend more money on the care of the forests.

During the year 1894–95 the income from State forests was distributed as follows:

Wood	$6,170,000
Minor products	670,000
Grazing	780,000
Other incomes	750,000
Total income	8,370,000

The expenditures for the same year were:

For administration (pay of officers, foresters, etc.)	$2,200,000
For cutting timber and removing it	1,350,000
Other work	760,000
Forest school	46,000
Total recurring expenses	4,356,000
For survey and other extraordinary work	300,000
Total expenditure	4,656,000

leaving a net revenue of $3,714,000, or 44 per cent of the gross income.

It is of special interest to note that the expense of fire protection amounted, under these most extraordinary circumstances, only to $130,000, or 1.6 per cent of the gross income, and that for cultural work, the horror of the American anti-forest proclaimer, only $150,000, or 1.8 per cent of the gross income, was paid.

The forest laws of India were like those of most countries, a matter of growth and adaptation, with the important difference, however, that the well-defined object of preserving to this great and peculiar people a continuous supply of the all-essential timber was steadily kept in mind. The principal acts are those of 1865, 1869, and especially the "Indian forest act" of 1878, with secondary legislation applying to particular localities, such as the act of 1881 for Burma, and 1882 for Madras and others.

In general these forest laws provide for the establishment of permanent or "reserved" State forests, to be managed according to modern forestry principles. They provide for a suitable force of men; give the forest officers certain police powers; prohibit unwarranted removal of forest products, the setting of fires, or otherwise injuring the forest property. The laws also regulate grazing and the chase by permit systems, and prescribe rules by which the work of the department is carried on, as well as the manner in which officers are engaged, promoted, etc. Since the peculiar circumstances required men specially fitted and trained, schools were established to furnish the recruits for this steadily growing service. The one at Coopers Hill, England, where a thorough course is intended to prepare men for the superior staff positions, and the Imperial school at Dehra Dun, which is to supply the great number of the executive staff, the young men starting in usually as guards or rangers at a pay of about $25 per month, working their way up to places worth $70 per month, and if well suited, eligible for further promotion. In the Dehra Dun school and the executive staff the native element is fast making itself felt, and there is little doubt that the men of India will soon be able to manage the forests of their own native land.

F. PRINCIPLES OF SILVICULTURE.

How Trees Grow.

Trees, like most other plants, originate from seed, build up a body of cell tissues, form foliage, flower, and fruit, and take up food material from the soil and air, which they convert into cellulose and other compounds, from which all their parts are formed. They rely, like other plants, upon moisture, heat, and light as the means of performing the functions of growth. Yet there are some peculiarities in their behavior, their life and growth, which require special attention on the part of a tree grower or forest planter.

FOOD MATERIALS AND CONDITIONS OF GROWTH.

Trees derive their food and solid substance in part from the air and in part from the soil. The solid part of their bodies is made up of cellulose, which consists largely of carbon (44 per cent of its weight), with hydrogen and oxygen added in almost the same proportions as in water. The carbon is derived from the carbonic acid of the air, which enters into the leaves, and under the influence of light, air, and water is there decomposed; the oxygen is exhaled; the carbon is retained and combined with elements derived from the water, forming compounds, such as starch, sugar, etc., which are used as food materials, passing down the tree through its outer layers to the very tips of the roots, making new wood all along the branches, trunk, and roots.

This process of food preparation, called "assimilation," can be carried on only in the green parts, and in these only when exposed to light and air; hence foliage, air, and light at the top are essential prerequisites for tree growth, and hence, other conditions being favorable, the more foliage and the better developed it is and the more light this foliage has at its disposal for its work, the more vigorously will the tree grow.

In general, therefore, pruning, since it reduces the amount of foliage, reduces also for the time the amount of wood formed; and just so shading, reducing the activity of foliage, reduces the growth of wood.

SOIL CONDITIONS.

From the soil trees take mainly water, which enters through the roots and is carried through the younger part of the tree to the leaves, to be used in part on its passage for food and wood formation and in part to be given up to the air by transpiration.

In a vigorously growing tree the solid wood substance itself will contain half its weight in the form of water chemically combined, and the tree, in addition, will contain from 40 to 65 per cent and more of its dry weight in water mechanically or hygroscopically held. This last, when the tree is cut, very largely evaporates; yet well-seasoned wood still contains 10 to 12 per cent of such water. The weight of a green tree—a pine, for instance—is made up in round numbers of about 30 per cent of carbon and 70 per cent of water, either chemically or hygroscopically held, while a birch contains a still larger percentage of water.

The largest part of the water which passes through the tree is transpired—i. e., given off to the air in vapor. The amounts thus transpired during the season vary greatly with the species of tree, its age, the amount of foliage at work, the amount of light at its disposal, the climatic conditions (rain, temperature, winds, relative humidity), and the season. These amounts are, however, very large when compared with the quantity retained; so that while an acre of forest

may store in its trees, say, 1,000 pounds of carbon, 15 to 20 pounds of mineral substances, and 5,000 pounds of water in a year, it will have transpired—taken up from the soil and returned to the air—from 500,000 to 1,500,000 pounds of water (one-quarter to one-half as much as agricultural crops).

Mineral substances are taken up only in very small quantities, and these are mostly the commoner sorts, such as lime, potash, magnesia, and nitrogen. These are carried in solution to the leaves, where they are used (as also on their passage through the tree), with a part of the water, in food preparation. The main part of the mineral substances taken up remains, however, as the water transpires, in the leaves and young twigs, and is returned to the soil when the leaves are shed or when the tree is cut and the brush left to decompose and make humus. The mineral constituents of the tree remain as ashes when wood is burned, the remaining elements passing into the atmosphere in the form of gas.

Hence the improvement of the fertility of the soil by wood crops is explained, the minerals being returned in more soluble form to the soil; as also the fact that wood crops do not exhaust the soil of its minerals, provided the leaves and litter are allowed to remain on the ground.

For this reason there is no necessity of alternating wood crops, as far as their mineral needs are concerned; the same kind of trees can be grown on the same soil continuously, provided the soil is not allowed to deteriorate from other causes.

As the foliage can perform its work of food assimilation only when sufficient water is at its disposal, the amount of growth is also dependent not only on the presence of sufficient sources of supply, but also on the opportunity had by the roots to utilize the supply, and this opportunity is dependent upon the condition of the soil. If the soil is compact, so that the rain water can not penetrate readily and runs off superficially, or if it is of coarse grain and so deep that the water rapidly sinks out of reach of the roots and can not be drawn up by capillary action, the water supply is of no avail to the plants; but if the soil is porous and moderately deep (depth being the distance from the surface to the impenetrable subsoil, rock, or ground water), the water not only can penetrate, but also can readily be reached and taken up by the roots.

The moisture of the soil being the most important element in it for tree growth, the greatest attention must be given to its conservation and most advantageous distribution through the soil.

No trees grow to the best advantage in very dry or very wet soil, although some can live and almost thrive in such unfavorable situations. A moderately but evenly moist soil, porous and deep enough or fissured enough to be well drained, and yet of such a structure that the water supplies from the depths can readily be drawn up and become available to the roots—that is the soil on which all trees grow most thriftily.

The agriculturist procures this condition of the soil as far as possible by plowing, drainage, and irrigation, and he tries by cultivating to keep the soil from compacting again, as it does under the influence of the beating rain and of the drying out of the upper layers by sun and wind.

The forest grower can not rely upon such methods, because they are either too expensive or entirely impracticable. He may, indeed, plow for his first planting, and cultivate the young trees; but in a few years this last operation will become impossible and the effects of the first operation will be lost. He must, therefore, attain his object in another manner, namely, by shading and mulching the soil. The shading is done at first by planting very closely, so that the ground may be protected as soon as possible from sun and wind, and by maintaining the shade well throughout the period of growth. This shade is maintained, if necessary, by more planting, and in case the main crop in later life thins out inordinately in the crowns or tops, or by the accidental death of trees, it may even become desirable to introduce an underbrush.

The mulching is done by allowing the fallen leaves and twigs to remain and decay, and form a cover of rich mold or humus. This protective cover permits the rain and snow waters to penetrate without at the same time compacting the soil, keeping it granular and in best condition for conducting water, and at the same time preventing evaporation at the surface.

The soil moisture, therefore, is best maintained by proper soil cover, which, however, is needful only in naturally dry soils. Wet soils, although supporting tree growth, do not, if constantly wet, produce satisfactory wood crops, the growth being very slow. Hence they must be drained and their water level sunk below the depth of the root system.

Irrigation is generally too expensive to be applied to wood crops, except perhaps in the arid regions, where the benefit of the shelter belt may warrant the expense.

Attention to favorable moisture conditions in the soil requires the selection of such kinds of trees as shade well for a long time, to plant closely, to protect the woody undergrowth (but not weeds), and to leave the litter on the ground as a mulch.

Different species, to be sure, adapt themselves to different degrees of soil moisture, and the crop should therefore be selected with reference to its adaptation to available moisture supplies.

While, as stated, all trees thrive best with a moderate and even supply of moisture, some can get along with very little, like the conifers, especially pines; others can exist even with an excessive supply, as the bald cypress, honey locust, some oaks, etc. The climate, however, must also be considered in this connection, for a tree species, although succeeding well enough on a dry soil in an atmosphere which does not require much transpiration, may not do so in a drier climate on the same soil.

In the selection of different kinds of trees for different soils, the water conditions of the soil should therefore determine the choice.

LIGHT CONDITIONS.

To insure the largest amount of growth, full enjoyment of sunlight is needed. But as light is almost always accompanied by heat and relative dryness of air, which demands water from the plant, and may increase transpiration from the leaves inordinately, making them pump too hard, as it were, young seedlings of tree species whose foliage is not built for such strains require partial shading for the first year or two. The conifers belong to this class.

The great extent of our country, involving as it does wide ranges of climatic and soil conditions, makes it impossible to give complete lists of trees adapted to various soil conditions in all parts of the United States. The safest rule for the planter to follow is to be guided in his selection of species by the character of the growth in similar sites near the land to be planted. Speaking generally, the following lists may be useful:

Trees that endure wet soils.—South of the Ohio River and central Missouri: Bald cypress, white cedar, red cedar, black gum, holly, water oak, red birch, cottonwood. North of the Ohio and Missouri rivers: White cedar, arbor vitæ, larch, black spruce, cottonwood, white willow, sycamore.

Dry soils.—South of the Ohio River and central Missouri: Mesquite (Texas and southwest), black oak, hackberry, shortleaf pine. North of Ohio and Missouri rivers: Bull pine, jack pine, scrub pine, white oak, post oak, jack oak.

The remaining species, north and south, require moist or fresh soils for their development, conditions under which all species succeed best.

In later life the light conditions exert a threefold influence on the development of the tree, namely, with reference to soil conditions, with reference to form development, and with reference to amount of growth.

The art of the forester consists in regulating the light conditions so as to secure the full benefit of the stimulating effect of light on growth without its deteriorating influences on the soil and on form development.

As we have seen, shade is desirable in order to preserve soil moisture. Now, while young trees of all kinds, during the "brush" stage of development, have a rather dense foliage, as they grow older they vary in habit, especially when growing in the forest. Some, like the beech, the sugar maple, the hemlock, and the spruce, keep up a dense crown; others, like the chestnut, the oaks, the walnut, the tulip tree, and the white pine, thin out more and more, and when fully grown have a much less dense foliage; finally, there are some which do not keep up a dense shade for any length of time, like the black and honey locust, with their small, thin leaves; the catalpa, with its large but few leaves at the end of the branchlets only, and the larch, with its short, scattered bunches of needles. So we can establish a comparative scale of trees with reference to the amount of shade which they can give continuously, as densely foliaged and thinly foliaged, in various gradations. If we planted all beech or sugar maple, the desirable shading of the soil would never be lacking, while if we planted all locust or catalpa the sun would soon reach the soil and dry it out, or permit a growth of grass or weeds, which is worse, because these transpire still larger

quantities of water than the bare ground evaporates or an undergrowth of woody plants would transpire. Of course, a densely foliaged tree has many more leaves to shed than a thinly foliaged one, and therefore makes more litter, which increases the favorable mulch cover of the soil. Another reason for keeping the ground well shaded is that the litter then decomposes slowly, but into a desirable humus, which acts favorably upon the soil, while if the litter is exposed to light, an undesirable, partly decomposed "raw" humus is apt to be formed.

Favorable soil conditions, then, require shade, while wood growth is increased by full enjoyment of light; to satisfy both requirements, mixed planting, with proper selection of shade-enduring and light-needing species, is resorted to.

As the different species afford shade in different degrees, so they require for their development different degrees of light. The dense foliage of the beech, with a large number of leaves in the interior of the crown, proves that the leaves can exist and perform their work with a small amount of light; the beech is a shade enduring tree. The scanty foliage of poplars and pines shows that these are light-needing trees; hence they are never found under the dense shade of the former, while the shade enduring can develop satisfactorily under the light shade of the thin-foliaged kinds. Very favorable soil conditions increase the shade endurance of the latter, and climatic conditions also modify their relative position in the scale.

All trees ultimately thrive best—i. e., grow most vigorously—in the full enjoyment of light, but their energy then goes into branching. Crowded together, with the side light cut off, the lower lateral branches soon die and fall, while the main energy of growth is put into the shaft and the height growth is stimulated. The denser shade of the shade enduring kinds, if placed as neighbors to light-needing ones, is most effective in producing this result, provided that the light is not cut off at the top; and thus, in practice, advantage is taken of the relative requirements for light of the various species.[1]

The forester finds in close planting and in mixed growth a means of securing tall, clear trunks, free from knots, and he is able, by proper regulation of light conditions, to influence the form development, and also the quality of his crop, since slow growth and rapid growth produce wood of different character.

There are some species which, although light foliaged and giving comparatively little shade, are yet shade-enduring—i. e., can subsist, although not develop favorably, under shade; the oaks are examples of this kind. Others, like the black cherry, bear a dense crown for the first twenty years, perhaps, seemingly indicating great shade endurance; but the fact that the species named soon clears itself of its branches and finally has a thin crown indicates that it is light-needing, though a good shader for the first period of its life. Others, again, like the catalpa, which is shady and shade enduring, as the difficulty with which it clears itself indicates, leaf out so late and lose their foliage so early that their shading value is thereby impaired. Black locust and honey locust, on the other hand, leave no doubt either as to their light-needing or their inferior shading quality.

That soil conditions and climatic conditions also modify crown development and shade endurance has been well recognized abroad, but in our country this influence is of much more importance on account of the great variation in those conditions. Thus the box elder, an excellent shader in certain portions of the West, is a failure as soil cover in others where it nevertheless will grow.

We see, then, that in determining the shading value as well as the shade endurance of one species in comparison with another, with reference to forestry purposes, not only soil and climate but also the character of foliage and its length of season must be considered.

As to shade endurance the more valuable species of the United States, including exotics, may be classed as follows:

Light-demanding from seedling stage: Aspen, cottonwood, black walnut, black locust, honey

[1] This relation of the different species to varying light conditions, their comparative shading value and shade endurance, is one of the most important facts to be observed and utilized by the forester. European foresters have done this, but since they had to deal with only a few species and over a limited territory, they could quite readily classify their trees with reference to their shade endurance, and take it for granted that shade endurance and density of foliage or shading value were more or less identical. With our great wealth of useful species it will be necessary and profitable to be more exact in the classification.

locust, white ash, green ash, red pine, bull pine, sycamore, larch, black birch, mesquite, the hickories.

Light-demanding when mature, but enduring moderate shade in youth: The oaks, white pine, black cherry, catalpa, silver maple, red maple, the elms, tulip, yellow birch.

Shade-enduring: Beech, sugar maple, box elder, mulberry, hackberry, hemlock, red cedar, Douglas spruce, white fir, white spruce, arbor vitæ, and white cedar.

PHYSIOLOGY OF TREE GROWTH.

As we have seen, root and foliage are the main life organs of the tree. The trunk and branches serve to carry the crown upward and expose it to the light, which is necessary in order to prepare the food and increase the volume of the tree, and also as conductors of food materials up and down between root and foliage. A large part of the roots, too, aside from giving stability to the tree, serve only as conductors of water and food material; only the youngest parts, the fibrous roots, beset with innumerable fine hairs, serve to take up the water and minerals from the soil. These fine roots, root hairs, and young parts are therefore the essential portion of the root system. A tree may have a fine, vigorous-looking root system, yet if the young parts and fibrous roots are cut off or allowed to dry out, which they readily do—some kinds more so than others—thereby losing their powers to take up water, such a tree is apt to die. Under very favorable moisture and temperature conditions, however, the old roots may throw out new sprouts and replace the fibrous roots. Some species, like the willows, poplars, locusts, and others, are especially capable of doing so. All trees that "transplant easily" probably possess this capacity of renewing the fibrous roots readily, or else are less subject to drying out. But it may be stated as a probable fact that most transplanted trees which die soon after the planting do so because the fibrous roots have been curtailed too much in taking up, or else have been allowed to dry out on the way from the nursery or forest to the place of planting; they were really dead before being set. Conifers—pines, spruces, etc.—are especially sensitive; maples, oaks, catalpas, and apples will, in this respect, stand a good deal of abuse.

Hence, in transplanting, the first and foremost care of the forest grower, besides taking the seedling up with least injury, is the proper protection of its root fibers against drying out.

The water, with the minerals in solution, is taken up by the roots when the soil is warm enough, but to enable the roots to act they must be closely packed with the soil. It is conveyed mostly through the outer, which are the younger, layers of the wood of root, trunk, and branches to the leaves. Here, as we have seen, under the influence of light and heat it is in large part transpired and in part combined with the carbon into organic compounds, sugar, etc., which serve as food materials. These travel from the leaf into the branchlet, and down through the outer layers of the trunk to the very tips of the root, forming new wood all the way, new buds, which lengthen into shoots, leaves, and flowers, and also new rootlets. To live and grow, therefore, the roots need the food elaborated in the leaves, just as the leaves need the water sent up from the roots.

Hence the interdependence of root system and crown, which must be kept in proportion when transplanting. At least, the root system must be sufficient to supply the needs of the crown.

"SAP UP AND SAP DOWN."

The growing tree, in all its parts, is more or less saturated with water, and as the leaves, under the influence of sun and wind and atmospheric conditions generally transpire, new supplies are taken in through the roots and conveyed to the crown. This movement takes place even in winter, in a slight degree, to supply the loss of water by evaporation from the branches. In the growing season it is so active as to become noticeable; hence the saying that the sap is "up," or "rising," and when, toward the end of the season, the movement becomes less, the sap is said to be "down." But this movement of water is always upward; hence the notion that there is a stream upward at one season and in one part of the tree and a stream downward at another season and perhaps in another part of the tree is erroneous. The downward movement is of food materials, and the two movements of water upward and food downward take place simultaneously and depend, in part at least, one upon the other, the food being carried to the young parts, wherever required, by a process of diffusion from cell to cell known as "osmosis."

These food materials are, by the life processes of the active cells, changed in chemical composition as need be, from sugar, which is soluble, into starch, which is insoluble, and back into sugar, and combined with nitrogenous substances to make the cell-forming material, protoplasm (fig. 27).

In the fall, when the leaves cease to elaborate food, both the upward and the downward movement, more or less simultaneously, come to rest (the surplus of food materials, as starch, and sometimes as sugar, being stored for the winter in certain cell tissues), to begin again simultaneously when in spring the temperature is high enough to reawaken activity, when the stored food of last year is dissolved and started on its voyage. The exact manner in which this movement of water upward and food materials downward takes place, and the forces at work, are not yet fully understood, nor is there absolute certainty as to the parts of the tree in which the movement takes place. It appears, however, that while all the so-called "sapwood" is capable of conducting water (the heartwood is probably not), the most active movement of both water and food materials takes place in the cambium (the growing cells immediately beneath the bark) and youngest parts of the bark.

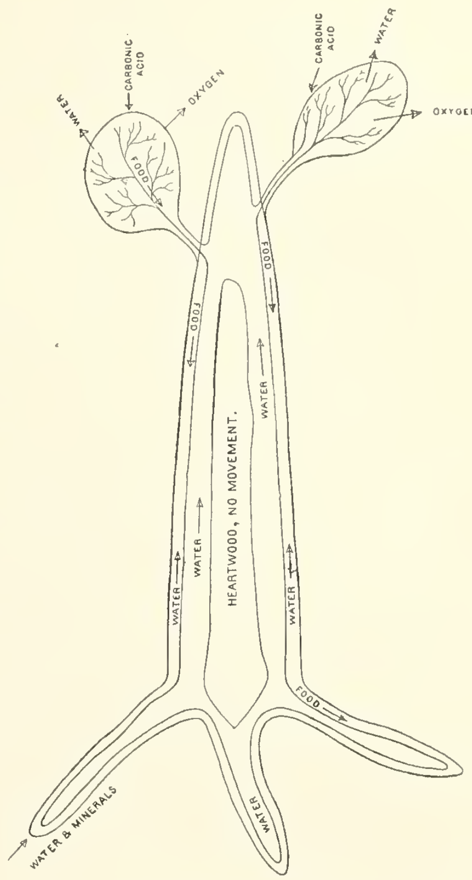


FIG. 27.—Physiological importance of different parts of the tree; pathways of water and food materials. (Schematic.)

The deductions from these processes important to the planter are: That injury to the living bark or bast means injury to growth, if not destruction to life; that during the period of vegetation transplanting can be done only with great caution; that the best time to move trees is in the fall, when the leaves have dropped and the movement of water and food materials has mostly ceased, or in spring, before the movement begins again, the winter being objectionable only because of the difficulty of working the soil and of keeping the roots protected against frost. All things considered, spring planting, before activity in the tree has begun, is the best, although it is not impossible to plant at other times.

In the making of protoplasm and the plant tissues resulting from its growth, many chemical changes occur within the plant, as a result of which not only woody tissue, which may be considered the permanent essential product of growth, but also many by-products are formed. It not infrequently happens that what has here been termed the by-product is of greater commercial importance than the wood itself. Thus among familiar woody species the India rubber tree is only valued for its sap, the logwood of Central America for dyeing, the cinchona trees for their alkaloid (quinine products), etc. Again, some of our most important timber trees yield also useful by-products. The maple yields millions of pounds of excellent sugar, the longleaf pine is the principal source of the resin and turpentine supply of the world, and the bark of hemlock and of certain oaks furnish most of the tannin used in American tanneries.

PROGRESS OF DEVELOPMENT.

Like wheat or corn, the tree seeds require as conditions for sprouting sufficient moisture, warmth, and air. The seeds, however, differ from grain in that most of the kinds lose their power of germination easily; with few exceptions (locust, pine, spruce), they can not be kept for any length of time.

The first leaves formed often differ essentially in shape from those of the mature tree, which may cause their being confounded with other plants, weeds, etc.

The little seedlings of many, especially the conifers, are quite delicate, and remain very small the first season; they need, therefore, the protecting shade of mother trees, or artificial shading, and also protection against weeds. The amount of light or shade given requires careful regulation for some of them; too much light and heat will kill them, and so will too much shade. This accounts for the failure of many seedlings that spring up in the virgin forest.

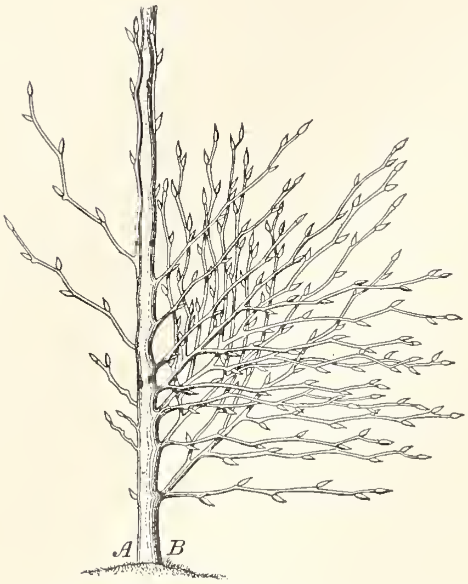


FIG. 28.—Bud development of beech. B, as it would be if all formed buds were to live; A, as it is, many buds failing to develop.

The planter, then, is required to know the nature and the needs of the various kinds of seeds and seedlings, so as to provide favorable conditions, when he will avoid sowing in the open field such as require the care which it is impractical to give outside of the nursery.

GROWTH IN LENGTH AND RAMIFICATION.

While the stalk of wheat or corn grows for one season, exhausts itself in seed production, and then dies, the tree continues to grow from season to season, in length as well as in thickness. The growth in length of shaft and branches proceeds from buds, made up of cell tissues, which can subdivide and lengthen into shoots, as well as make leaves. These buds are formed during summer, and when winter begins contain embryo leaves, more or less developed, under the protecting cover of scales (fig. 29). When spring stimulates the young plant to new activity, the buds swell, shed their scales, distend their cells, increasing their number by subdivision, and thus the leaves expand, and the bud lengthens into a shoot and twig. During the season new buds are formed, and the whole process repeats itself from year to year, giving rise to the ramification and height growth of the tree. The end buds being mostly stronger and better developed, the main axis of tree or branch increases more rapidly than the rest. All these buds originate from the youngest, central part of the shoot, the pith, and hence when the tree grows in thickness, enveloping the base of the limbs, their connection with the pith can always be traced. This is the usual manner of bud formation; in addition, so-called "adventitious" buds may be formed from the young living wood in later life, which are not connected with the pith. Such buds are those which develop into sprouts from the stump when the tree is cut; also those which give rise to what are known as "water sprouts." Many buds, although formed, are, however, not developed at once, and perhaps not at all, especially as the tree grows older; these either die or remain "dormant," often for a hundred years, to spring into life when necessary (fig. 29).

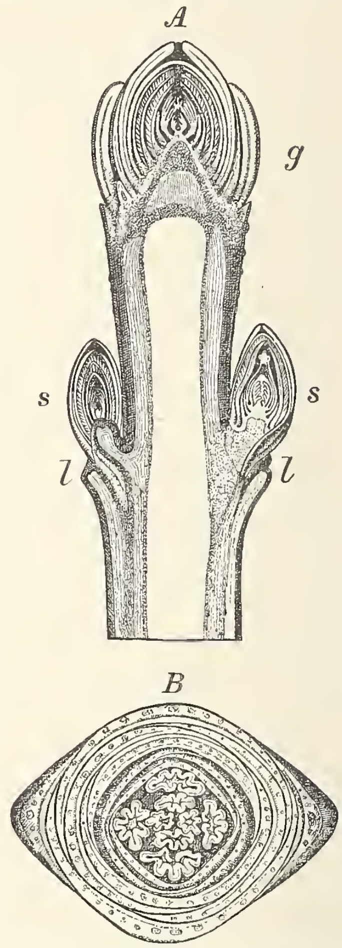


FIG. 29.—Buds of maple. A, longitudinal section through tip of a maple twig; g, end bud; s, lateral buds; l, scars of leaves of last season. B, cross section through end bud, showing folded leaves in center and scales surrounding them.

The fact that each ordinary limb starts as a bud from the pith is an important one to the timber grower; it explains knotty timber and gives him the hint that in order to obtain clear timber the branches first formed must be soon removed, either by the knife or by proper shading, which kills the branches and thus "clears" the shaft.

The planter has it also in his power to influence the form development of the tree by removing

some of the buds, giving thereby better chance to the remaining ones. This pruning of buds is, where practicable, often better practice than the pruning of limbs.

Since the tree does not grow in length except by its buds, it is evident that a limb which started to grow at the height of 6 feet has its base always 6 feet from the ground, and if allowed to grow to size, must be surrounded by the wood which accumulates on the main stem or trunk. If a limb is killed and broken off early, only a slender stub composed entirely of rapidly decaying sapwood is left, occasioning, therefore, only a small defect in the heart of the tree; but if left to grow to considerable age, the base of the limb is incased by the wood of the stem, which, when the tree is cut into lumber, appears as a knot. The longer the limb has been allowed to grow the farther out is the timber knotty and the thicker is the knot. If the limb remained alive, the knot is "sound," closely grown together with the fibers of the tree. If the limb died off, the remaining stub may behave in different ways. In pines it will be largely composed of heartwood, very resinous and durable; separated from the fibers of the overgrowing wood, it forms a "loose" knot, which is apt to fall out of a board, leaving a hole.

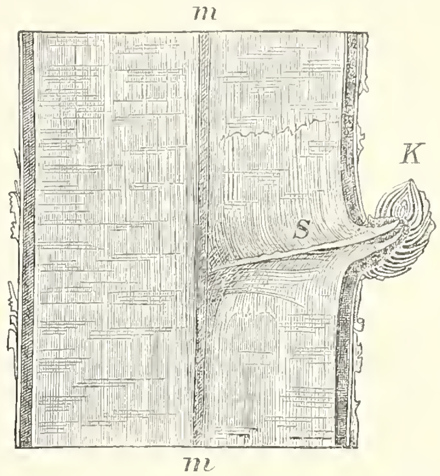


FIG. 30.—Dormant bud K, on a 12-year-old branch of beech. The bud is still capable of development and is connected with the pith, mm, of the stem by a fine trace of pith, S.

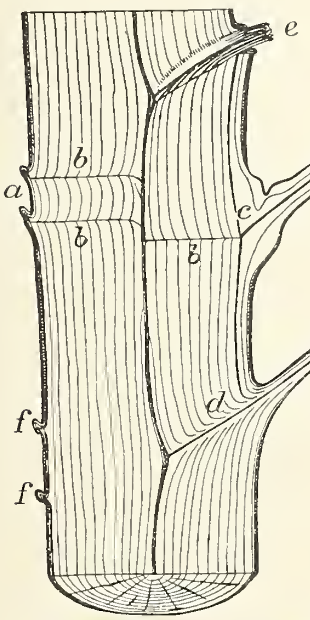


FIG. 31.—Section through a 12-year-old stem of beech, showing manner of bud and limb formation. a, dormant buds; b, their trace of pith extending to the pith of the stem; c, a limb which started two years ago from a dormant bud; d, normal limb; e, a limb dead for four years; f, adventitious buds.

In broad-leaved trees, where no resin assists in the process of healing, the stub is apt to decay, and this decay, caused by the growth of fungi, is apt to penetrate into the tree (fig. 32). In parks and orchards pruning is resorted to, and the cuts are painted or tarred to avoid the decay. In well-managed forests and dense woods in general the light is cut off, the limb is killed when young and breaks away, the shaft "clears itself," and the sound trunk furnishes a good grade of material. The difference in development of the branch system, whether in full enjoyment of light, in open stand, or with the side light cut off, in dense position, is shown in the accompanying illustration (fig. 33).

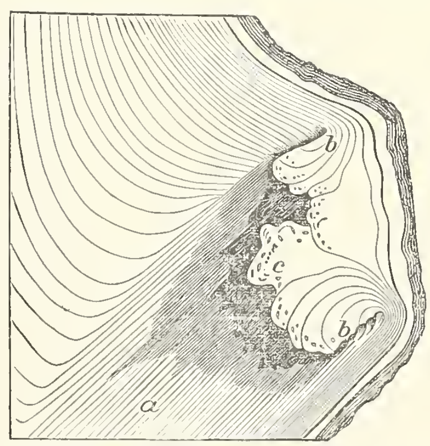


FIG. 32.—Section through a partly decayed knot in oak wood. a, wood of the knot; b and c, wood callus of the stem covering the wound; shaded portion, decayed wood; black part, a cavity remaining.

Both trees start alike; the one retains its branches, the other loses them gradually, the stubs being in time overgrown; finally, the second has a clear shaft, with a crown concentrated at the top, while the first is beset with branches and branch stubs for its whole length (fig. 34).

When ripped open lengthwise, the interior exhibits the condition shown in fig. 36, the dead parts of the knot being indicated in heavier shading. Since the branches grow in more or less regular whorls, several knots, stumps, or limbs are met every 6 to 24 inches through the entire stem.

Hence, in forest planting, trees are placed and kept for some time close together, in order to decrease the branching in the lower part of the tree and thus produce a clean bole and clear lumber.

GROWTH IN THICKNESS.

The young seedling and the young shoot of the older tree much resemble in interior structure that of any herbaceous plant, being composed of a large amount of pith, loose squarish cells, and a few bundles of long fibers symmetrically distributed about the center, the whole covered with a thin skin or epidermis. Each strand or bundle of fibers, called fibro-vascular (fiber-vessel) bundles, consists of two kinds, namely, wood fibers on the inner side and bast fibers of different structure on the outer side. Between these two sets of fibers, the bast and the wood, there is a row of cells which form the really active, growing part of the plantlet, the cambium. The cambium cells are actively subdividing and expanding, giving off wood cells to the interior and bast cells to the exterior, and extending at the same time sidewise, until at the end of the season not only are the wood and bast portions increased in lines radiating from the center, but the cambium layer, the wood cells, and the bast cells of all the bundles (scattered at the beginning) join at the sides to form a complete ring, or rather cylinder, around the central pith. Only here and there the pith cells remain, interrupting the wood cylinder and giving rise to the system of cells known as medullary rays. The cross section now shows a comparatively small amount of pith and bast or bark and a larger body of strong wood fibers. The new shoot at the end, to be sure, has the same appearance and arrangement as the young plantlet had, the pith preponderating, and the continuous cylinder of cambium, bast, and wood being separated into strands or bundles.

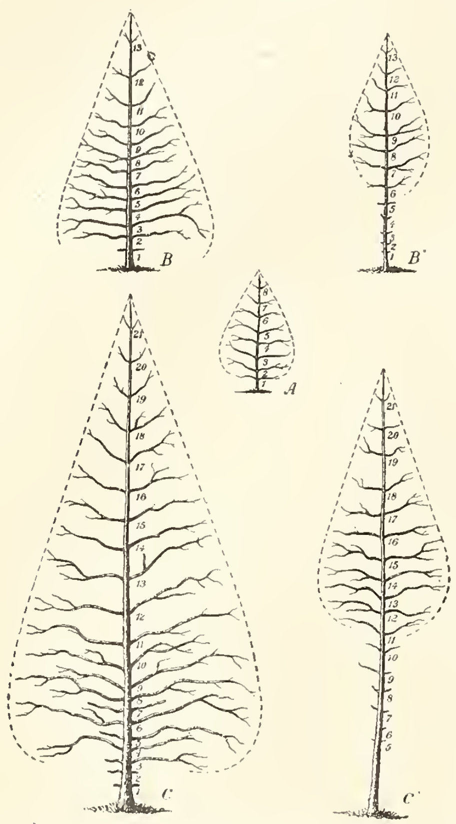


FIG. 33.—Development in and out of the forest. *A*, young tree alike in both cases; *B* and *C*, successive stages of tree grown in the open; *B'* and *C'*, corresponding stages of the tree grown in the forest. Numbers refer to annual growth in height.

During the season, through the activity of the cambial part of the bundles, the same changes take place in the new shoot as did the previous year in the young seedling, while at the same time the cambium in the yearling part also actively subdivides, forming new wood and bast cells, and thus a second ring, or rather cylinder, is formed. The cambium of the young shoot is always a continuation of that of the ring or cylinder formed the year before, and this cambium cylinder always keeps moving outward, so that at the end of the season, when activity ceases, it is always the last minute layer of cells on the outside of the wood, between wood proper and bark. It is here, therefore, that the life of the tree lies, and any injury to the cambium must interfere with the growth and life of the tree.

The first wood cells which the cambium forms in the spring are usually or always of a more open structure, thin-walled, and with a large opening or "lumen" comparable to a blown-up paper bag; so large, in fact, sometimes, is the "lumen" that the width of the cells can be seen on a cross section with the naked eye, as, for instance, in oak, ash, elm, the so-called "pores" are this open wood formed in spring. The cells which are formed later in summer have mostly thick walls, are closely crowded and compressed, and show a very small opening or "lumen," being comparable, perhaps, to a very thick, wooden box. They appear in the cross section not only denser but of a deeper color, on account of their crowded, compressed condition and thicker walls. Since at the beginning of the next season again thin-walled cells with wide openings or lumina are formed, this difference in the appearance of "spring wood" and "summer wood" enables us to distinguish the layer of wood formed each year. This "annual ring" is more conspicuous in some kinds than in others. In the so-called "ring-porous" woods, like oak, ash, elm, the rings are easily distinguished by the open spring wood; in the conifers,

especially pines, by the dark-colored summer wood; while in maple, birch, tulip, etc., only a thin line of flattened, hence darker and regularly aligned, summer cells, often hardly recognizable, distinguishes the rings from each other. Cutting through a tree, therefore, we can not only ascertain its age by counting its annual layers in the cross section, but also determine how much wood is formed each year (fig. 36). We can, in fact, retrace the history of its growth, the vicissitudes through which it has passed, by the record preserved in its ring growth.

To ascertain the age of a tree correctly, however, we must cut so near to the ground as to include the growth of the first year's little plantlet. Any section higher up shows as many years too few as it took the tree to reach that height.

This annual-ring formation is the rule in all countries which have distinct seasons of summer and winter and temporary cessation of growth. Only exceptionally a tree may fail to make its growth throughout the whole length, on account of loss of foliage and other causes, and occasionally, when its growth has been disturbed during the season, a "secondary" ring, resembling the annual ring, and distinguishable only by the expert, may appear and mar the record.

To the forest planter this chapter on ring growth is of great importance, because not only does this feature of tree life afford the means of watching the progress of his crop, calculating the amount of wood formed, and therefrom determining when it is most profitable for him to harvest (namely, when the annual or periodic wood growth falls below a certain amount), but since the proportion of summer wood and spring wood determines largely the quality of the timber, and since he has it in his power to influence the preponderance of the one or other by adaptation of species to soils and by their management, ring growth furnishes an index for regulating the quality of his crop.

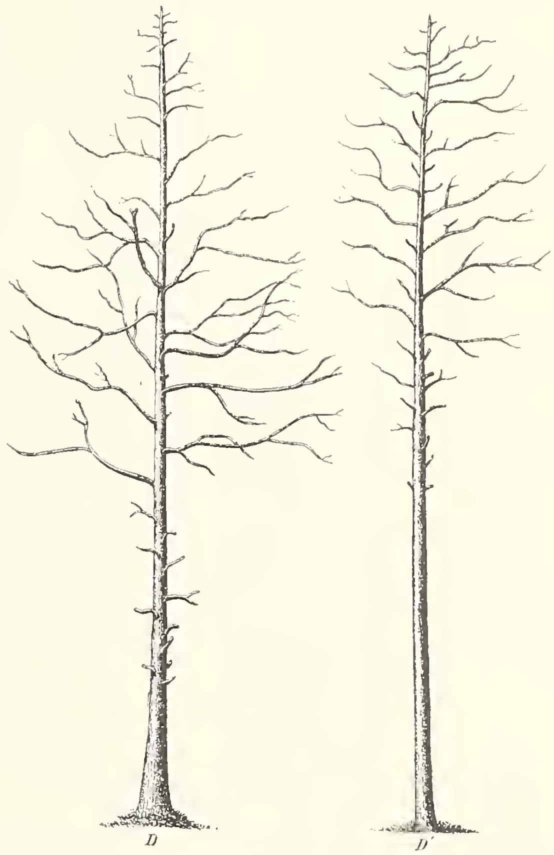


FIG. 34.—Trees in and out of the forest. *D*, tree grown in the open; *D'*, tree grown in the forest.

FORM DEVELOPMENT.

If a tree is allowed to grow in the open, it has a tendency to branch, and makes a low and spreading crown. In order to lengthen its shaft and to reduce the number of branches it is necessary to narrow its growing space, to shade its sides so that the lower branches and their foliage do not receive light enough to perform their functions. When the side shade is dense enough these branches die and finally break off under the influence of winds and fungous growth; wood then forms over the scars and we get a clean shaft which carries a crown high up beyond the reach of shade from neighbors.

The branches being prevented from spreading out, the shaft is forced to grow upward, and hence, when crowded by others, trees become taller and more cylindrical in form, while in the open, where they can spread, they remain lower and more conical in form (figs. 37 and 38).

There are, to be sure, different natural types of development, some, like the walnuts, oaks, beeches, and the broad leafed trees generally, having greater tendency to spread than others, like spruces, firs, and conifers in general, which lengthen their shaft in preference to spreading, even in the open. This tendency to spreading is also influenced by soil conditions and climate, as well as by the age of the tree. When the trees cease to grow in height their crowns broaden, and this takes place sooner in shallow soils than in deep, moist ones; but the tendency can be checked and all can be made to develop the shaft at the expense of the branches by proper shading from the sides.

It follows that the forest planter, who desires to produce long and clean shafts and best working quality of timber, must secure and maintain side shade by a close stand, while the landscape gardener, who desires characteristic form, must maintain an open stand and full enjoyment of light for his trees.

Now, as we have seen, different species afford different amounts of shade, and in proportion to the shade which they afford can they endure shade. The beech or sugar maple or spruce, which maintain a large amount of foliage under the dense shade of their own crown, show that their leaves can live and functionate with a small amount of light. They are shade-enduring trees. On the other hand, the black walnut, the locust, the catalpa, the poplars, and the larch show by the manner in which their crowns thin out, the foliage being confined to the ends of the branches, that their leaves require more light—they are light-needing trees; so that the scale which arranges the trees according to the amount of shade they exert serves also to measure their shade endurance.

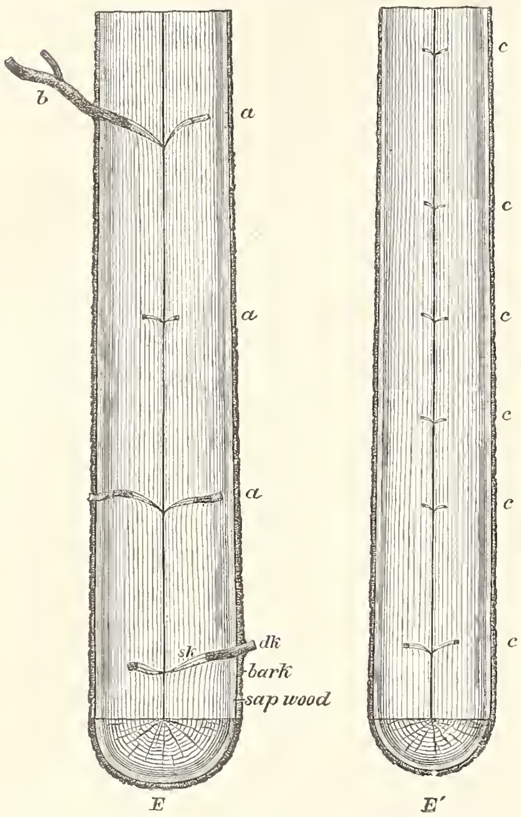


FIG. 35.—Sections of logs showing the relative development of knots. *E*, from tree grown in the open; *E′*, from tree grown in a dense forest; *a* and *c*, whorls of knots; *b*, dead limb; *sk*, "sound knot;" *dk*, "dead knot."

In making, therefore, mixed plantations the different kinds must be so grouped and managed that the shady trees will not outgrow and overtop the light-needing. The latter must either have the start of the former or must be quicker growers.

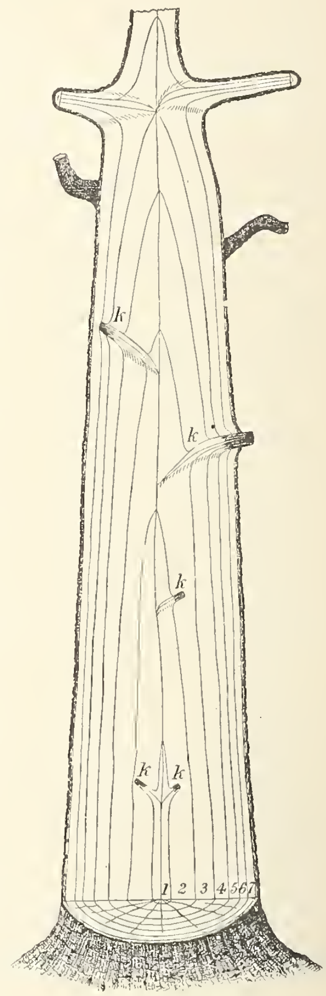


FIG. 36.—Scheme to illustrate the arrangement of annual growth. 1, 2, 3, etc., represent the parts of the stem grown during the first, second, third, etc., twenty years of the life of the tree. *k*, knots; the shaded part of each is the "dead knot" of lumber.

RATE OF GROWTH.

Not only do different species grow more or less rapidly in height and girth, but there is in each species a difference in the rate of growth during different periods of life and a difference in the persistence of growth.

It stands to reason that trees grow differently in different soils and situations, and hence we can not compare different species with respect to their rate of growth except as they grow under the same conditions.

Thus the black walnut may grow as fast as or faster than the ash on a rich, deep, moist, warm soil, but will soon fall to the rear in a wetter, colder, and shallower soil.

Given the same conditions, some species will start on a rapid upward growth at once, like the poplars, aspen, locust, and silver maple, making rapid progress (the most rapid from their tenth to their fifteenth year), but decreasing soon in rate and reaching their maximum height early. Others, like the spruce, beech, and sugar maple, will begin slowly, often occupying several,

sometimes as many as 10 to 15, years before they appear to grow at all, their energy all going into root growth. Then comes a period of more and more accelerated growth, which reaches its maximum rate at 25 or 30 years; and when the cottonwood or aspen has reached the end of its growth in height the spruce or pine is still at its best rate, and continues to grow for a long time at that rate. In later life the rate decreases, yet height growth sometimes does not cease altogether for centuries. As a rule, the light-needing species are the ones which show the rapid height growth at the start, while the shade enduring are slow at the start, but persistent growers.

This fact is important in explaining the alternations of forest growth in nature; the persistent shade-enduring species crowd out the light-needing, and the latter rapidly take possession of any openings that fire or storm has made. It is also important with reference to the management of wood crops and starting of mixed plantations; the light-needing species must be mixed only with such shade-enduring species as are slower growers than themselves.


FIG. 37.—Oak tree grown in the open.

The diameter growth shows also periodic changes in its rate, and is, of course, influenced in the same way by soil, climate, and light conditions as the height growth.

In the juvenile or brush stage, lasting 6 to 10 years in light-needing and 20 to 40 years in shade enduring species, the diameter grows comparatively little, all energy being directed to height growth and root growth. When the crown has been definitely formed more food material is available for wood formation, and the increase in foliage is accompanied by a more rapid increase of trunk diameter; in favorable situations the highest rate occurs between the fortieth and sixtieth years; in the poorer situations, between the fiftieth and eightieth years, which rate continues for some time. Then comes a period of slower rate, which finally in old age dwindles down almost to zero.

But neither the diameter growth nor the width of the annual rings alone tells us directly what amount of wood is forming. The outer rings, being laid over a larger circumference, although narrower than the preceding rings, may yet have greater cubic contents. The statements of diameter growth are, therefore, misleading if we are interested in knowing how much wood is forming.


FIG. 38.—Maple tree grown in the forest.

Accordingly the growth in volume must be considered separately, as determined by the enlargement of the cross-section area and the height. The growth in volume or mass accretion is quite small in young trees, so that when wood is cut young the smallest amount of crop per year is harvested, while, if it is allowed to grow, an increase more than proportionate to the number of years may be obtained.

Only when the tree has a fully developed crown does it begin to make much wood. Its volume growth progresses then at compound interest, and continues to do so for decades, and sometimes for a century or more.

On poorer sites the rate is slower, but remains longer on the increase, while on good sites the maximum rate is soon reached.

Of course in a forest, where light conditions are not most favorable, because form development and soil conditions require shade, the total wood formation is less than in an isolated tree favorably placed. Just so the dominant trees in a forest—i. e., those which have their crowns above all others—show, of course, the advantage they have over the inferior trees which are suffering from the shade of their neighbors.

Finally, if we would take into consideration an entire forest growth, and determine, for instance, how much wood an acre of such forest produces at different periods, we must not overlook the fact that the number of trees per acre changes as the trees grow older. Some of them are overshaded and crowded out by the others, so that a young growth of spruce might start with 100,000 little seedlings to the acre, of which in the twentieth year only 10,000 would be alive,

while in the fortieth year the number would be reduced to 1,200, and in the hundredth year to 280. Hence the rate of growth of any single tree gives no idea of what the acre of forest will do.

Thus, while a single good white pine might grow the fastest in volume when about one hundred years old, then making wood at the rate of, say, 1.5 cubic feet per year, an acre of pine on good soil, containing about 1,600 trees, may make the most wood in the thirtieth year, then growing at the rate of 170 cubic feet per acre, while in the hundredth year the rate would not exceed 70 cubic feet; and an acre of pine in a poorer location, with about 1,400 trees, may make the most wood in the fortieth year, at the rate of 100 cubic feet per acre.

From the consideration of the relation of light conditions to soil conditions, to form development, and to rate of growth, we may make the following deductions of interest to the forest planter:

In order to secure the best results in wood production, in quantity and quality, at the same time preserving favorable soil conditions, the forest should be composed of various species, a mixture of light-needing and shade enduring kinds. The light-needing ones should be of quicker growth; the shady ones, in larger numbers, should be slower growers. For the first fifteen to twenty-five years the plantation should be kept as dense as possible, to secure clear shafts and good growth in height; then it should be thinned, to increase crown development and diameter growth; the thinning, however, is not to be so severe that the crowns can not close up again in two or three years; the thinning is to be repeated again and again, always favoring the best developed trees.

RATE OF GROWTH.

The more commonly cultivated trees may be classified with reference to their rate of growth, as follows:

Rapid growers to maturity: Cottonwood, aspen, tulip, loblolly pine, white pine, white elm, box elder, silver maple, jack pine.

Rapid growing in youth, but much slower in age: Black cherry, long-leaf pine, short-leaf pine, catalpa, black walnut, black locust, honey locust, the birches.

Slow but persistent growers: White ash, sugar maple, the oaks, the hickories, the spruces, and hemlock.

REPRODUCTION.

All trees reproduce themselves naturally from seed. Man can secure their reproduction also from cuttings or layers; and some kinds can reproduce themselves by shoots from the stump when the parent tree has been cut. This latter capacity is possessed in a varying degree by different species; chestnuts, oaks, elms, maples, poplars, and willows are most excellent sprouters; most conifers do not sprout at all, and the shoots of those that do sprout soon die (Sequoia or California redwood seems to be an exception). Sprouts of broad-leafed trees develop differently from seedlings, growing very rapidly at first, but soon lessening in the rate of growth and never attaining the height and perhaps not the diameter of trees grown from the seed; they are also shorter lived. With age the stumps lose their capacity for sprouting. To secure best results, the parent tree should be cut close to the ground in early spring, avoiding severe frost, and a sharp cut should be made which will not sever the bark from the trunk.

Not all trees bear seed every year, and plentiful seed production, especially in a forest, occurs, as a rule, periodically. The periods differ with species, climate, and season.

Not all seeds can germinate, and in some species the number of seeds that can germinate is very small, and they loose their power of germination when kept a few hours, like the willows. Others, if kept till they have become dry, will "lie over" in the soil a year or more before germinating. The same thing will occur if they are covered too deep in the soil, provided they germinate at all under such conditions.

In order to germinate, seeds must have warmth, air, and moisture. The preparation of a seed bed is, therefore, necessary in order to supply these conditions in most favorable combination. In the natural forest millions of seeds rot or dry without sprouting, and millions of seedlings sprout, but soon perish under the too dense shade of the mother trees.

Man, desiring to reproduce a valuable wood crop, can not afford to be as lavish as nature, and must therefore improve upon nature's methods, making more careful preparation for the production

of his crop, either by growing the seedlings in nurseries and transplanting them, or else by cutting away the old growth in such a manner as to secure to the young self-grown crop better chances for life and development.

How to Plant a Forest.

Forest planting and tree planting are two different things. The orchardist, who plants for fruit; the landscape gardener, who plants for form; the roadside planter, who plants for shade, all have objects in view different from that of the forest planter, and therefore select and use their plant material differently. They deal with single individual trees, each one by itself destined for a definite purpose. The forester, on the other hand, plants a crop like the farmer; he deals not with the single seed or plant, but with masses of trees; the individual tree has value to him only as a part of the whole. It may come to harvest for its timber, or it may not come to harvest, and yet have answered its purpose as a part of the whole in shading the ground or acting as nurse or "forwarder" as long as it was necessary.

His object is not to grow trees, but to produce wood, the largest amount of the best quality per acre, whether it be stored in one tree or in many, and his methods must be directed to that end.

As far as the manner of setting out plants or sowing seeds is concerned, the same general principles and the same care in manipulation are applicable as in any other planting, except as the cost of operating on so large a scale may necessitate less careful methods than the gardener or nurseryman can afford to apply; the nearer, however, the performance of planting can be brought to the careful manner of the gardener, the surer the success. The principles underlying such methods have been discussed in the chapter "How trees grow;" in the present chapter it is proposed to point out briefly the special considerations which should guide the forest planter in particular.

WHAT TREES TO PLANT.

Adaptability to climate is the first requisite in the species to be planted.

It is best to choose from the native growth of the region which is known to be adapted to it. With regard to species not native, the reliance must be placed upon the experience of neighboring planters and upon experiment (at first on a small scale), after study of the requirements of the kinds proposed for trial.

Adaptation must be studied, not only with reference to temperature ranges and rainfall, but especially with reference to atmospheric humidity and requirements of transpiration.

Many species have a wide range of natural distribution, and hence of climatic adaptation. If such are to be used, it is important to secure seeds from that part of the range of natural distribution where the plants must be hardiest, i. e., the coldest and driest region in which it occurs, which insures hardy qualities in the offspring. For instance, the Douglas spruce from the humid and evenly tempered Pacific slope will not be as hardy as that grown from seed collected on the dry and frigid slopes of the Rockies. Lack of attention to this requisite accounts for many failures. It must also be kept in mind that while a species may be able to grow in another than its native climate, its wood may not there have the same valuable qualities which it develops in its native habitat.

Adaptability to soil must be studied less with reference to mineral constituents than to physical condition. Depth and moisture conditions, and the structure of the soil, which influences the movement of water in it, are the most important elements. While all trees thrive best in a moist to "fresh" soil of moderate depth (from 2 to 4 feet) and granular structure, some can adapt themselves to drier or wetter, shallow, and compact soils. Fissures in rocks into which the roots can penetrate often stand for depth of soil, and usually aid in maintaining favorable moisture conditions. In soils of great depth (i. e., from the surface to the impenetrable subsoil) and of coarse structure water may drain away so fast as not to be available to the roots.

Soil moisture must always be studied in conjunction with atmospheric moisture, for while a species may thrive in an arid soil, when the demands of transpiration are not great, it may not do so when aridity of atmosphere is added. Trees of the swamp are apt to be indifferent to soil moisture and to thrive quite well, if not better, in drier soils.

Adaptability to site.—While a species may be well adapted to the general climatic conditions of a region, and in general to the soil, there still remains to be considered its adaptability to the

particular "site," under which term we may comprise the total effect of general climate, local climate, and soil. The general climatic conditions are locally influenced, especially by the slope, exposure, or aspect, and the surroundings. Thus we know that eastern exposures are more liable to frost, western exposures more liable to damage from winds, southern more apt to be hot and to dry out, and northern to be cooler and damper, having in consequence a shorter period of vegetation. Hollows and lowlands are more exposed to frosts and more subject to variations in soil moisture, etc.

Hence for these various situations it is advisable to select species which can best withstand such local dangers.

The use value, or utility, of the species is next to be considered. This must be done with reference to the commercial and domestic demand, and the length of time it takes the species to attain its value. The greater variety of purposes a wood may serve—i. e., the greater its general utility—and the sooner it attains its use value, the better. White pine for the northeastern States as a wood is like the apple among fruits, making an all-round useful material in large quantities per acre in short time. Tulip poplar, applicable to a wider climatic range, is almost as valuable, while oak, ash, and hickory are standard woods in the market. Other woods are of limited application. Thus the black locust, which grows most quickly into useful posts, has only a limited market, much more limited than it should have; hickory soon furnishes valuable hoop poles from the thinnings, and later the best wagon material, not, however, large quantities in a short time; while black walnut of good quality is very high in price, the market is also limited, and the dark color of the heartwood, for which it is prized, is attained only by old trees. The black cherry, used for similar purposes, attains its value much sooner.

By planting various species together, variety of usefulness may be secured and the certainty of a market increased.

The forest value of the species is only in part expressed by its use value. As has been shown in another place, the composition of the crop must be such as to insure maintenance of favorable soil conditions as well as satisfactory development of the crop itself. Some species, although of high use value, like ash, oak, etc., are poor preservers of soil conditions, allowing grass and weeds te enter the plantation and to deteriorate the soil under their thin foliage. Others, like beech, sugar maple, box elder, etc., although of less use value, being dense foliaged and preserving a shady crown for a long time, are of great forest value as soil improvers.

Again, as the value of logs depends largely on their freedom from knots, straightness, and length, it is of importance to secure these qualities. Some valuable species, if grown by themselves, make crooked trunks, do not clean their shafts of branches, and are apt to spread rather than lengthen. If planted in close companionship with others, they are forced by these "nurses" or "forwarders" to make better growths and clean their shafts of branches.

Furthermore, from financial considerations, it is well to know that some species develop more rapidly and produce larger quantities of useful material per acre than others; thus the white pine is a "big cropper," and combining with this a tolerably good shading quality, and being in addition capable of easy reproduction, it is of highest "forest value."

Hence, as the object of forestry is to make money from continued wood crops, use value and forest value must both be considered in the selection of materials for forest planting.

Mutual relationship of different species, with reference especially to their relative height growth and their relative light requirements, must be considered in starting a mixed plantation.

Mixed forest plantations (made of several kinds) have so many advantages over pure plantations (made of one kind) that they should be preferred, except for very particular reasons. Mixed plantations are capable of producing larger quantities of better and more varied material, preserve soil conditions better, are less liable to damage from winds, fires, and insects, and can be more readily reproduced.

The following general rules should guide in making up the composition of a mixed plantation:

a. Shade-enduring kinds should form the bulk (five-eighths to seven-eighths) of the plantation, except on specially favored soils, where no deterioration is to be feared from planting only light-needing kinds, and in which case these may even be planted by themselves.

b. The light-needing trees should be surrounded by shade-enduring of slower growth, so that the former may not be overtopped, but have the necessary light and be forced by side shade to straight growth.

c. Shade-enduring species may be grown in admixture with each other when their rate of height growth is about equal or when the slower-growing kind can be protected against the quicker-growing (for instance, by planting a larger proportion of the former in groups or by cutting back the latter).

d. The more valuable timber trees which are to form the main crop should be so disposed individually and planted in such numbers among the secondary crop or nurse crop that the latter can be thinned out first without disturbing the former.

In localities which for climatic reasons prevent a wide range of choice of species a light-needing rapid growing species may be used as a nurse, forming as much as three-fourths of the plantation, provided the remaining trees are disposed according to rule *a*, if care be taken to remove the nurses as soon as they interfere with the permanent trees. In this case the rapid-growing species is used only to create more favorable conditions for the permanent trees and to protect them during infancy.

Where a plantation of lighter-foliaged trees has been made (black walnut, for instance), it can be greatly improved by "underplanting" densely with a shade-enduring kind, which will choke out weed growth, improve the soil, and thereby advance the growth of the plantation.

The selection and proper combination of species with reference to this mutual relationship to each other and to the soil are the most important elements of success.

Availability of the species also still needs consideration in this country; for, although a species may be very well adapted to the purpose in hand, it may be too difficult to obtain material for planting in quantity or at reasonable prices. While the beech is one of the best species for shade endurance, and hence for soil cover, seedlings can not be had as yet in quantity. Western conifers, although promising good material for forest planting, are at present too high priced for general use. Some eastern trees can be secured readily—either their seed or seedlings—from the native woods; others must be grown in nurseries before they can be placed in the field.

Whether to procure seeds or plants, and, if the latter, what kind, depends upon a number of considerations. The main crop, that which is to furnish the better timber, had best be planted with nursery-grown plants, if of slow-growing kinds, perhaps once transplanted, with well-developed root systems, the plants in no case to be more than 2 to 3 years old. The secondary or nurse crop may then be sown or planted with younger and less costly material taken from the woods or grown in seed beds, or else cuttings may be used.

In some localities—for instance, the Western plains—the germinating of seeds in the open field is so uncertain and the life of the young seedlings for the first year or two so precarious that the use of seeds in the field can not be recommended. In such locations careful selection and treatment of the planting material according to the hardships which it must encounter can alone insure success.

Seedlings from 6 to 12 inches high furnish the best material. The planting of larged-sized trees is not excluded, but is expensive and hence often impracticable, besides being less sure of success, since the larger-sized tree is apt to loose a greater proportion of its roots in transplanting.

METHODS OF PLANTING.

Preparation of soil is for the purpose of securing a favorable start for the young crop; its effects are lost after the first few years. Most land that is to be devoted to forest planting does not admit of as careful preparation as for agricultural crops, nor is it necessary where the climate is not too severe and the soil not too compact to prevent the young crop from establishing itself. Thousands of acres in Germany are planted annually without any soil preparation, yearling pine seedlings being set with a dibble in the unprepared ground. This absence of preparation is even necessary in sandy soils like that encountered in the sandhills of Nebraska, which may, if disturbed, be blown out and shifted. In other cases a partial removal of a too rank undergrowth or soil cover and a shallow scarifying or hoeing are resorted to, or else furrows are thrown up and the trees set out in them.

In land that has been tilled, deep plowing (10 to 12 inches) and thorough pulverizing give the best chances for the young crop to start. For special conditions, very dry or very moist situations, special methods are required. The best methods for planting in the semiarid regions of the far West have not yet been developed. Thorough cultivation, as for agricultural crops, with subsequent culture, is successful, but expensive. A plan which might be tried would consist in

breaking the raw prairie in June and turning over a shallow sod, sowing a crop of oats or alfalfa, harvesting it with a high stubble, then opening furrows for planting and leaving the ground between furrows undisturbed, so as to secure the largest amount of drainage into the furrows and a mulch between the rows.

The time for planting depends on climatic and soil conditions and the convenience of the planter. Spring planting is preferable except in southern latitudes, especially in the West, where the winters are severe and the fall apt to be dry, the soil therefore not in favorable condition for planting.

The time for fall planting is after the leaves have fallen; for spring planting, before or just when life begins anew. In order to be ready in time for spring planting, it is a good practice to take up the plants in the fall and "heel them in" over winter (covering them, closely packed, in a dry trench of soil). Conifers can be planted later in spring and earlier in fall than broad-leafed trees.

The density of the trees is a matter in which most planters fail. The advantages of close planting lie in the quicker shading of the soil, hence the better preservation of its moisture and improved growth and form development of the crop. These advantages must be balanced against the increased cost of close planting. The closer the planting the sooner will the plantation be self-sustaining and the surer the success.

If planted in squares, or, better still, in quincunx order (the trees in every other row alternating at equal distances), which is most desirable on account of the more systematic work possible and the more complete cover which it makes, the distance should not be more than 4 feet, unless for special reasons and conditions, while 2 feet apart is not too close, and still closer planting is done by nature with the best success.

The following numbers of trees per acre are required when planting at distances as indicated:

1½ by 1½ feet	19,360	2 by 4 feet	5,445
1½ by 2 feet	14,520	3 by 3 feet	4,840
2 by 2 feet	10,890	3 by 4 feet	3,630
2 by 3 feet	7,260	4 by 4 feet	2,722

To decrease expense, the bulk of the plantation may be made of the cheapest kinds of trees that may serve as soil cover and secondary or nurse crop, the main crop of from 300 to 600 trees to consist of better kinds and with better planting material, mainly of light-needing species. These should be evenly disposed through the plantation, each closely surrounded by the nurse crop. It is of course understood that not all trees grow up; a constant change in numbers by the death (or else timely removal) of the overshaded takes place, so that the final crop shows at 100 years a close cover, with hardly 300 trees to the acre.

After-culture is not entirely avoidable, especially under unfavorable climatic conditions and if the planting was not close enough. Shallow cultivation between the rows is needed to prevent weed growth and to keep the soil open until it is shaded by the young trees, which may take a year with close planting and two or three years with rows 4 by 4 feet apart, the time varying also with the species.

It is rare that a plantation succeeds in all its parts; gaps or fail places occur, as a rule, and must be filled in by additional planting as soon as possible if of larger extent than can be closed up in a few years by the neighboring growth.

When the soil is protected by a complete leaf canopy, the forest crop may be considered as established, and the after-treatment will consist of judicious thinning.

The diagrams following present planting schemes illustrative of the rules given above, the species being adapted to planting on the Western plains.

RULES 1 AND 2.—*One acre planted 3 by 3 feet requires 4,840 trees.*

B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M
M	O	M	Ch	M	D	M	L	M	D	M	Ch	M	D	M	E	M	O
B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M
M	L	M	D	M	C	M	D	M	L	M	D	M	C	M	D	M	L
B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M
M	D	M	L	M	P	M	Ch	M	D	M	L	M	P	M	Ch	M	D
B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M
M	C	M	D	M	E	M	D	M	C	M	D	M	L	M	D	M	C
B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M
M	P	M	Ch	M	D	M	C	M	P	M	Ch	M	D	M	L	M	P
B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M
M	L	M	D	M	C	M	D	M	L	M	D	M	C	M	D	M	L
B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M
M	D	M	E	M	P	M	Ch	M	B	M	L	M	P	M	L	M	D
B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M
M	C	M	D	M	L	M	D	M	C	M	D	M	L	M	D	M	C
B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M
M	O	M	Ch	M	D	M	L	M	P	M	Ch	M	B	M	S	M	O

	Trees.
Shade enduring.	
B—Box elder	1,210
M—Russian mulberry	2,420
D—Douglas spruce	454
Ch—Black cherry	151
C—Catalpa	151
Light demanding.	
L—Black locust	303
P—Bull pine	132
O—Bur oak	19
Total	4,840

In this mixture the boxelder and Russian mulberry trees are the nurse trees, and it may be necessary to cut them all out within from ten to twenty years. They will not have attained more than stake or small fuel size in that time, but by shading the remaining trees on the sides they will have prevented their formation of side branches, and thus forced them to straight single stems.

After the removal of the nurse trees there will remain 1,210 trees to the acre, standing 6 by 6 feet apart. Of these the pine, oak, and locust, numbering 454, are more light demanding than the spruce, cherry, and catalpa, which number 756. It will be observed that each of these light-demanding trees is neighbored by more shade-enduring kinds.

The next trees to be removed will be the locusts and catalpas, which should be fit for fence posts by the time the plantation becomes sufficiently crowded to make their removal necessary. The cutting of these, when between 15 and 30 years old, will leave 756 trees per acre, of which oaks, pines, and cherry (which demands more light with age), making two-fifths of the whole number, will be light demanding, and the spruce shade enduring.

The thinning from now on will depend entirely upon the requirements of the standing trees, the purpose of getting the greatest possible amount of timber of the highest quality as the final crops being kept constantly in view.

This discussion of the plan is based upon the impossible supposition that all the trees will live until cut out. Much thinning, in point of fact, will result from the dying of trees, so that the ideal perfect stand is never reached in practice.

The scheme indicated, it is perhaps needless to add, is given merely to illustrate the practice, and can be adapted to any suitable species which the planter may be able to secure.

One acre planted 3 by 3 feet requires 4,840 trees.

A	A	A	A	A	A	A	A	A	A
A	S	A	C	A	S	A	C	A	S
A	A	A	A	A	A	A	A	A	A
A	P	A	P	A	P	A	S	A	P
A	A	A	A	A	A	A	A	A	A
A	S	A	C	A	S	A	C	A	S
A	A	A	A	A	A	A	A	A	A
A	P	A	S	A	P	A	S	A	P
A	A	A	A	A	A	A	A	A	A
A	S	A	C	A	S	A	C	A	S

	Trees.
A—Aspen	3,630
S—White spruce	605
C—Red cedar	302
P—White pine	303
Total	4,840

This plan illustrates the use of a rapid-growing light demanding species (aspen) as a protection for several conifers which are difficult to establish in the open, especially in the plains. It will be noticed that two of the conifers, the spruce and cedar, are shade-enduring species, and that the light-demanding pines will be surrounded by the shaders when the aspen has been cut out. This use of the aspen as a soil cover was suggested by an examination of cut-over pine land in northern Minnesota, where the aspen quickly takes the ground when the pine is removed, and the pine seedlings appear thickly under its protection. It will be observed that, taking out the aspen, the plan is based on the same principles of light influence as is the plan above.

PLANTING IN WASTE PLACES.

Aside from the fence rows, which are usually the worst weed beds of the farm, there are many small areas in the average farm which from a variety of causes are unprofitable for cropping. These may well be planted to trees.

In the most favored region the farm "of which every foot is arable" is seldom seen. Even on the richest of prairie farms the crests of the rolling surface are apt to become impoverished after years of tillage in spite of the best efforts of the farmer, and when the crops fail to pay for the labor expended on them the land is as surely "waste" as though it were undrained swamp or rocky hillside. In the less densely populated parts of the country, where land is cheap, the fields are abandoned when this stage is reached. In the East and South, where the entire country was once covered with forest, natural reforestation soon takes place, and in a few years the old fields are clothed with pines, spruces, and deciduous trees, the varieties being dependent upon the adjacent growth. Within this area the farmer can always control the character of the forest growths on the waste lands of his farm, either by planting or by use of the ax, or both, and there is oftentimes great need of good judgment in cutting out inferior trees or undesirable varieties.

Few farmers seem to have realized the great value of a close-planted, dense-foliaged grove as a conservator of moisture. The snows accumulating in such groves are shaded from the sun, and long after the adjacent fields are bare the snow is slowly melting and the water trickling down over the plowed fields, which are thus thoroughly saturated. The summer rains are also saved to the farm by the same means. Following the deep-descending roots of the trees, they are

retained in the lower strata of the soil and then pass to the adjoining lands and are brought within reach of the growing plants.

It is not to be supposed that limited plantations, confined to the waste places of the farm, would have an appreciable effect on the general climate of a region, for the influences must be great that can affect atmospheric conditions over a wide area. Locally, however, the planting of hilltops and the consequent heightening of elevations will often result in the creation of air currents that will prevent cold air from settling in the lowlands between, thus obviating late spring and early autumn frosts, and this protection can be made more efficient if the configuration of the neighboring lands be studied with a view to creating the strongest possible draft.

In regions where tender vegetables and fruits are largely cultivated such protection may be of primary importance, and the clearing of adjoining hill crests and slopes will often result in serious disturbance of the local climate.

In general, the climatic conditions of the forested area of the country are less extreme than those of the plains, but with the record of the three recent drought years the need of moisture conservation is apparent alike in the East and West.

While in the West the thin-soiled ridges are best devoted to tree growth for wind-breaks and snow catches, throughout the Eastern and Southern States such localities should be kept in trees for the prevention of erosion or gullying, one of the most troublesome results of tillage.

The general action of the elements in uneven or rolling surfaces invariably tends to carry the more fertile top mold of the higher ground, or at least the decaying vegetation on the surface, to the lower levels, which thus relatively increase in fertility at the expense of the elevations above them. In addition to this general tendency there have been deposited throughout the Northwestern States, by glacial and water action, drift soils containing a great quantity of bowlders, which are especially thick on the high ridges, making their cultivation very expensive. In many localities throughout the Mississippi Valley the trend of the underlying strata of rocks is upward, often coming so close to the surface in the ridge lands as to render them worthless for cultivation. Along many river and creek valleys the hills which confine the lowlands rise so abruptly as to make cultivation impracticable. These and many other special cases which might be mentioned constitute the waste highlands of farms, all of which should be devoted to forest-tree culture.

Trees, as has been seen, can exist and make a profitable growth on lands too poor to support farm crops, if the leaves, twigs, and fruit be permitted to lie on the ground and decay. When planted in the thin soil of a limestone hill crest, they may make very slow growth during the first few years; but as the soil becomes shaded by the tree tops the growth becomes more rapid, and when the trees have attained a strong foothold, their roots penetrating the crevices of the rocks to the water below, they grow with additional vigor. Yet, it is not to be expected that as vigorous growth can be secured in these high waste places as in the lower, moist, and deep soils. One has only to recall the general character of the waste places of the farm to realize how little can be gained from cropping them. The ridge soils are too thin to support a growth of cereal crops; the swamp soils are too wet for tillage; the cultivation of irregular plats of small extent becomes too expensive, by reason of the difficulties of plowing, seeding, and harvesting. Once in trees, these difficulties are reduced to a minimum. The thin soils of the ridges are protected from the weather by the tree crowns, and their decaying foliage gradually increases the fertility of the soil.

The odd corners and fence rows of American farms represent in the aggregate a great quantity of unproductive land, which might be planted to trees. Such limited areas, often composed of but a few square rods or very narrow strips, can not be treated as forests, but trees must be grown on them for special purposes, in which timber production will hardly be considered.

The highways throughout the farming districts of the United States may be bordered with trees, which, while giving shade, may be used as living fence posts, or may become valuable nut orchards, but in any event will afford protection, in winter and summer alike, to the traveler and to the adjacent fields. In Minnesota, Wyoming, and other Western States the highways are at least 66 feet wide, and often a hundred. These tracts, separated only by wire fences from the cultivated fields, are not merely waste lands, but for the most part veritable propigating beds for noxious weeds, which cause much loss to the farmer. Try as he may, he can not protect his lands from Russian thistle, mustard, and the numerous other weed pests so long as these broad highways exist as a seeding ground for them. If they were planted to trees, with a vigorous

undergrowth to protect the surface of the soil, they would not only make any weed growth impossible, but would also be a potent means of preventing the dissemination of weeds from one section to another, by arresting them when carried by the winds. In many of the Western States the farmer is permitted by law thus to plant a portion of the highway with trees.

Yet another form of waste land is to be considered, and here the farmer living within the forest area is much more concerned than the prairie dweller. Had the adaptability of soils to tillage been made the basis of clearing lands in the early days, there would be less talk of "thin" soils now, for on many farms lands were cleared which should never have been stripped of their first cover. Steep hillsides, rocky slopes, highlands with hardly a foot of soil between the surface and the underlying rock, have been denuded of their forest cover, and their subsequent tillage has been all but profitless to the farmer. With constant cropping they have become so impoverished that their cultivation has been abandoned. Yet they have still enough fertility to support a vigorous tree growth. On many New England farms such thin lands have been planted to white pine with the most encouraging results. In many rocky, drift, eroded, and exhausted hill farms there is a depth of soil sufficient for the requirements of all varieties of trees, and the farmer within the forest area has thus a wide range of choice in the selection of trees. He may grow timber for railroad ties, for posts, for telegraph poles, for lumber, and for many other purposes, using the species that is best adapted to his need and to his locality.

In the Southern States the loblolly and short-leaf pines can be quite as readily grown as the white pine at the North. The loblolly seems to consider the abandoned fields its heritage, for throughout the lower Atlantic and Gulf States it quickly covers the old fields with its seedlings, which grow rapidly.

THE FARM NURSERY.

When such species as catalpa, box elder, black locust, green ash, white elm, and silver maple can be bought for less than $2 per thousand for strong 1-year-old plants, it would seem cheaper to purchase than to grow from seed. But with land, tools, and teams at hand, a forest tree nursery can be cultivated at very little expense, and the farmer, by gathering seed of the native trees, and purchasing desirable seeds not to be had at home, can grow on a fraction of an acre seedlings enough for an extensive plantation.

Of the broad-leafed trees, the silver maples, elms, poplars, cottonwood, aspen, and willows ripen their seeds before midsummer. These should be planted as soon as ripe, care being taken not to cover the small seeds too deep. They will germinate in a few days, and by autumn will be of a size suitable for transplanting.

Of the species whose seeds ripen in autumn, those of the tulip, catalpa, honey locust, black locust, and Kentucky coffee tree should be thrashed from their pods when gathered and kept over winter in a cool place where they will neither dry out nor mold. Birch seeds soon lose their vitality if permitted to dry, and they should be stored in close boxes or jars and kept over winter in a cool cellar. When the soil is moist in the fall, birch may be sown before the ground freezes, but in the dry soil of the plains the seeds should be kept over winter. They must be sown in beds shaded as for conifers, and covered very lightly. The seed usually ripens in August in the Northern woods, and should be gathered at once, separated, and stored until planting time.

The sprouting of the seeds of other broad-leafed trees of the Northern forest flora is hastened by subjecting them to the action of frost. This is accomplished either by fall planting or by mixing the seeds with sand and placing them in boxes on the north side of an outbuilding or other protection from the sun, whence they should be planted as soon as possible in the spring, or even, when the ground is sufficiently thawed out, in late winter. The nuts and acorns may be simply spread on a well-drained surface and protected from drying by a few inches of leaves held down by boards; but they are more subject to the depredations of rodents when thus disposed of. The seeds of fruit trees, such as cherry, mulberry, osage orange, wild crab apple, and hawthorn, should be separated from the pulp by maceration and washing before storing. Cherry and mulberry seeds ripen during the summer, and as the fruit is much relished by birds, watchfulness is necessary to get them. They may be slightly dried after washing, and then mixed with sand. Some seeds, notably those of the hawthorns, are apt to lie over two or more years. Germination of such refractory seeds is hastened by soaking in water continuously for a week or more before planting.

When the soil is moist in the fall, the seeds of all trees which ripen after midsummer may be planted, and thus the labor of storing is saved. But spring planting is usually more satisfactory, because uniform conditions can be better maintained where the seeds have been properly stored. The soil is also usually in the best condition for receiving the seeds in the spring, and lighter covering is possible.

It must be remembered that the seed of the oaks, nuts, and cherries must not be permitted to become thoroughly dry. Chestnut, beech, and the oaks are especially delicate in this respect, so that with these species it is always safest to plant as soon as the seed is ripe.

The forest-tree nursery should be placed in deep, moist, well-drained loam, and should be thoroughly cultivated.

It should be so arranged as to reduce hand work to a minimum. All the tree seeds except birch and the conifers, which must be grown under screens, can be sown in drills, 3 or 4 feet apart, thus making horse cultivation possible.

Hand weeding is important, for the tiny seedlings of many trees are very delicate, and the more vigorous grasses will quickly choke them out if left unprotected. Where a large nursery is made, frequent use of the harrow-toothed cultivator is most desirable, for it keeps a dust blanket on the surface of the soil which prevents excessive evaporation and insures the most perfect soil conditions obtainable through culture. Prompt attention is a requisite of successful nursery management.

Seedlings of box elder, silver maple, red maple, catalpa, black locust, and cottonwood are rampant growers the first season, and their growth may be checked, to make transplanting less difficult, by sowing the seed thick in broad drills. Black wild cherry, the elm, the ash, honey locust, black walnut, tulip, crab apple, hackberry, linden, and coffee tree are of moderate growth and easily attain transplanting size the first year. The oaks and the nut trees generally, hard maple, beech, and hawthorn will usually be benefited by remaining two or three years in the nursery. The birches should be transplanted from the seed bed to the nursery row the second year, and set in permanent forest the third.

While the cone bearing trees are more difficult to manage than the broad-leafed species, it will be found advantageous to the farmer to grow his own conifers. Not only are coniferous trees (pines, spruces, cedars, larches, etc.) more difficult to transplant, but they are disastrously affected by the drying of their roots; and in the operations of commercial nurseries—digging, storing, and packing—as well as in transit, there is more or less danger from this cause. It will frequently happen, too, that plants thus injured, unless the injury be very severe indeed, will appear in good condition when received, so that the purchaser accepting them will be disappointed in his stand, whatever care he takes in planting the stock. Even should the cost of growing the cone-bearing trees be more than it would cost to purchase them, as will often be the case if the time of the grower be considered, the trees will prove cheaper in the end, because favorable weather can be chosen for transplanting them; they can be dug as needed, and absolutely protected from drying out during the brief interval between digging and planting.

Farmers living adjacent to the pineries can easily secure seed by gathering the cones just before they burst open and spreading them in a thin layer until sufficiently dry to open, when the seed will fall out. The same method is used in securing all seeds save the red cedar, the fruit of which is a gummy berry. The berries of the cedar should be soaked for several days in water, then rubbed together to remove as much of the gum as possible, when they may be planted or mixed in sand and kept frozen during winter. A bath in weak lye will hasten the cleaning process. The seeds of the remaining conifers are kept dry over winter. They can be purchased of leading seedsmen throughout the country, and, as a rule, come true to name, though difficulty regarding the Rocky Mountain species is sometimes experienced. As seeds lose their vitality to a considerable degree the second year, and to a much greater degree thereafter, it is important to secure them fresh.

A well-drained, preferably sandy, loam should be chosen and the seed bed prepared as is usual for cold frames, so that as soon as the seed is planted the bed can be shaded. It should be open to the air on all sides, and the seed may be sown broadcast in the bed, or in drills a few inches apart. The seed should be covered but little, if any, more than its own depth. Pine, spruce, and Douglas spruce seed usually germinates in eighteen to twenty days, red cedar in two to six months, and

larch in twenty to thirty days. Shortly after the trees are up, or at any time during the first summer, a disease called "damping off" is liable to attack them. This is a fungous growth, and results in the decay of the tiny seedlings at the ground. It is often very destructive. The only remedy is to sow clean dry sand among the seedlings and withhold water for a few days. This is not always effective, but it will usually check the disease.

The shade for the seed bed is variously made. In the large nurseries it is usually a shed, roofed and sided with laths, but this would be too expensive for a farm nursery. Useful shades are made by laying brush across supports or by bunches of rushes or swamp grass similarly placed, but of course these are more difficult to keep in order. Where proper attention is paid to ventilation, an inexpensive shade can be made by tacking cheap sheeting to a frame to rest upon supports running along the side of the bed.

It may be advisable sometimes to purchase one or two year old seedlings from reliable growers. They should be planted, in shaded beds, about 3 inches apart, in rows 6 to 12 inches apart. It will be necessary to keep them shaded one to three years, according to their rate of growth. The oftener the cone-bearing trees are transplanted before being set permanently the better, as by this process the growth of fibrous roots close to the collar is encouraged. Especial care must be taken in handling conifers to prevent their roots from drying in the least, as whenever the roots dry it is almost impossible to make the trees live. The seedlings should be packed in damp moss at the nursery, and as soon as received the roots should be puddled in liquid mud and heeled in in a shaded place. The heeling in should be carefully done, the fine soil pressing close upon the roots, but not covering the tops. In a shaded place the trees may be left thus until the roots begin growth. In planting it is best to carry the trees in a bucket, with just enough water to cover the roots. They should be planted firmly and be well trampled, and a little loose soil dusted over the trampled surface to prevent baking. No tree should be set much deeper than it stood before, and this is specially important in transplanting conifers.

Conifers are ready for setting in plantations when from two to six years old. Larches can usually be set when two or three years old, the pines and cedars when from three to five years old, and the spruces when from four to six years.

How to Treat the Wood Lot.

In the northeastern States it is the custom to have connected with the farm a piece of virgin woodland, commonly called the wood lot. Its object primarily is to supply the farmer with the firewood, fence material, and such dimension timbers as he may need from time to time for repairs on buildings, wagons, etc.

As a rule, the wood lot occupies, as it ought to, the poorer part of the farm, the rocky or stony, the dry or the wet portions, which are not well fitted for agricultural crops. As a rule, it is treated as it ought not to be, if the intention is to have it serve its purpose continuously; it is cut and culled without regard to its reproduction.

As far as firewood supplies go, the careful farmer will first use the dead and dying trees, broken limbs, and leavings, which is quite proper. The careless man avoids the extra labor which such material requires, and takes whatever splits best, no matter whether the material could be used for better purposes or not.

When it comes to the cutting of other material, fence rails, posts, or dimension timber, the general rule is to go into the lot and select the best trees of the best kind for the purpose. This looks at first sight like the natural, most practical way of doing. It is the method which the lumberman pursues when he "culls" the forest, and is, from his point of view perhaps, justifiable, for he only desires to secure at once what is most profitable in the forest. But for the farmer who proposes to use his wood lot continuously for supplies of this kind, it is a method detrimental to his object, and in time it leaves him with a lot of poor, useless timber which encumbers the ground and prevents the growth of a better crop.

Our woods are mostly composed of many species of trees; they are mixed woods. Some of the species are valuable for some special purposes, others are applicable to a variety of purposes, and again others furnish but poor material for anything but firewood, and even for that use they may not be of the best.

Among the most valuable in the northeastern woods we should mention the white pine—king of all—the white ash, white and chestnut oak, hickories, tulip tree, black walnut, and black cherry, the last three being now nearly exhausted; next, spruce and hemlock, red pine, sugar maple, chestnut, various oaks of the black or red oak tribe, several species of ash and birch, black locust; lastly, elms and soft maples, basswood, poplars, and sycamore.

Now, by the common practice of culling the best it is evident that gradually all the best trees of the best kinds are taken out, leaving only inferior trees or inferior kinds—the weeds among trees, if one may call them such—and thus the wood lot becomes well-nigh useless.

It does not supply that for which it was intended; the soil, which was of little use for anything but a timber crop before, is still further deteriorated under this treatment, and being compacted by the constant running of cattle, the starting of a crop of seedlings is made nearly impossible. It would not pay to turn it into tillage ground or pasture; the farm has by so much lost in value. In other words, instead of using the interest on his capital, interest and capital have been used up together; the goose that laid the golden egg has been killed.

This is not necessary if only a little system is brought into the management of the wood lot and the smallest care is taken to avoid deterioration and secure reproduction.

IMPROVEMENT CUTTINGS.

The first care should be to improve the crop in its composition. Instead of culling it of its best material, it should be culled of its weeds, the poor kinds, which we do not care to reproduce, and which, like all other weeds, propagate themselves only too readily. This weeding must not, however, be done all at once, as it could be in a field crop, for in a full-grown piece of woodland each tree has a value, even the weed trees, as soil cover.

The great secret of success in all crop production lies in the regulating of water supplies; the manuring in part and the cultivating entirely, as well as drainage and irrigation, are means to this end. In forestry these means are usually not practicable, and hence other means are resorted to. The principal of these is to keep the soil as much as possible under cover, either by the shade which the foliage of the tall trees furnishes, or by that from the underbrush, or by the litter which accumulates and in decaying forms a humus cover, a most excellent mulch.

A combination of these three conditions, viz, a dense crown cover, woody underbrush where the crown cover is interrupted, and a heavy layer of well-decomposed humus, gives the best result. Under such conditions, first of all, the rain, being intercepted by the foliage and litter, reaches the ground only gradually, and therefore does not compact the soil as it does in the open field, but leaves it granular and open, so that the water can readily penetrate and move in the soil. Secondly, the surface evaporation is considerably reduced by the shade and lack of air circulation in the dense woods, so that more moisture remains for the use of the trees. When the shade of the crowns overhead (the so-called "crown cover," or "canopy,") is perfect but little undergrowth will be seen; but where the crown cover is interrupted or imperfect an undergrowth will appear. If this is composed of young trees, or even shrubs, it is an advantage, but if of weeds, and especially grass, it is a misfortune, because these transpire a great deal more water than the woody plants and allow the soil to deteriorate in structure and therefore in water capacity.

Some weeds and grasses, to be sure, are capable of existing where but little light reaches the soil. When they appear it is a sign to the forester that he must be careful not to thin out the crown cover any more. When the more light-needing weeds and grasses appear it is a sign that too much light reaches the ground, and that the soil is already deteriorated. If this state continues, the heavy drain which the transpiration of these weeds makes upon the soil moisture, without any appreciable conservative action by their shade, will injure the soil still further.

The overhead shade or crown cover may be imperfect because there are not enough trees on the ground to close up the interspaces with their crowns, or else because the kinds of trees which make up the forest do not yield much shade; thus it can easily be observed that a beech, a sugar maple, a hemlock is so densely foliaged that but little light reaches the soil through its crown canopy, while an ash, an oak, a larch, when full grown, in the forest, allows a good deal of light to penetrate.

Hence, in our weeding process for the improvement of the wood crop, we must be careful not to interrupt the crown cover too much, and thereby deteriorate the soil conditions. And for the

same reason, in the selection of the kinds that are to be left or to be taken out, we shall not only consider their use value, but also their shading value, trying to bring about such a mixture of shady and less shady kinds as will insure a continuously satisfactory crown cover, the shade-enduring kinds to occupy the lower stratum in the crown canopy, and to be more numerous than the light-needing.

The forester, therefore, watches first the conditions of his soil cover, and his next care is for the condition of the overhead shade, the "crown cover;" for a change in the condition of the latter brings change into his soil conditions, and, inversely, from the changes in the plant cover of the soil he judges whether he may or may not change the light conditions. The changes of the soil cover teach him more often when "to let alone" than when to go on with his operations of thinning out; that is to say, he can rarely stop short of that condition which is most favorable. Hence the improvement cuttings must be made with caution and only very gradually, so that no deterioration of the soil conditions be invited. We have repeated this injunction again and again, because all success in the management of future wood crops depends upon the care bestowed upon the maintenance of favorable soil conditions.

As the object of this weeding is not only to remove the undesirable kinds from the present crop, but to prevent as much as possible their reappearance in subsequent crops, it may be advisable to cut such kinds as sprout readily from the stump in summer time—June or July—when the stumps are likely to die without sprouting.

It may take several years' cutting to bring the composition of the main crop into such a condition as to satisfy us.

METHODS OF REPRODUCING THE WOOD CROP.

Then comes the period of utilizing the main crop. As we propose to keep the wood lot as such, and desire to reproduce a satisfactory wood crop in place of the old one, this latter must be cut always with a view to that reproduction. There are various methods pursued for this purpose in large forestry operations which are not practicable on small areas, especially when these are expected to yield only small amounts of timber, and these little by little as required. It is possible, to be sure, to cut the entire crop and replant a new one, or else to use the ax skillfully and bring about a natural reproduction in a few years; but we want in the present case to lengthen out the period during which the old crop is cut, and hence must resort to other methods. There are three methods practicable.

We may clear narrow strips or bands entirely, expecting the neighboring growth to furnish the seed for covering the strip with a new crop—"the strip method;" or we can take out single trees here and there, relying again on an aftergrowth from seed shed by the surrounding trees—the "selection method;" or, finally, instead of single trees, we may cut entire groups of trees here and there in the same manner, the gaps to be filled, as in the other cases, with a young crop from the seed of the surrounding trees, and this we may call the "group method."

In *the strip method*, in order to secure sufficient seeding of the cleared strip, the latter must not be so broad that the seed from the neighboring growth can not be carried over it by the wind. In order to get the best results from the carrying power of the wind (as well as to avoid windfalls when the old growth is suddenly opened on the windward side) the strips should be located on the side opposite the prevailing winds. Oaks, beech, hickory, and nut trees in general with heavy seeds will not seed over any considerable breadth of strip, while with maple and ash the breadth may be made twice as great as the height of the timber, and the mother trees with lighter seeds, like spruce and pine, or birch and elm, may be able to cover strips of a breadth of three or four and even eight times their height. But such broad strips are hazardous, since with insufficient seed fall, or fail years in the seed, the strip may remain exposed to sun and wind for several years without a good cover and deteriorate. It is safer, therefore, to make the strips no broader than just the height of the neighboring timber, in which case not only has the seed better chance of covering the ground, but the soil and seedlings have more protection from the mother crop. In hilly country the strips must not be made in the direction of the slope, for the water would wash out soil and seed.

Every year, then, or from time to time, a new strip is to be cleared and "regenerated." But

if the first strip failed to cover itself satisfactorily the operation is stopped, for it would be unwise to remove the seed trees further by an additional clearing. Accordingly, this method should be used only where the kinds composing the mother crop are frequent and abundant seeders and give assurance of reseeding the strips quickly and successfully.

The other two methods have greater chances of success in that they preserve the soil conditions more surely, and there is more assurance of seeding from the neighboring trees on all sides.

The selection method, by which single trees are taken out all over the forest, is the same as has been practiced by the farmer and lumberman hitherto, only they have forgotten to look after the young crop. Millions of seed may fall to the ground and germinate, but perish from the excessive shade of the mother trees. If we wish to be successful in establishing a new crop it will be necessary to be ready with the ax all the time and give light as needed by the young crop. The openings made by taking out single trees are so small that there is great danger of the young crop being lost, or at least impeded in its development, because it is impracticable to come in time to its relief with the ax.

The best method, therefore, in all respects, is the *group method*, which not only secures continuous soil cover, chances for full seeding, and more satisfactory light conditions, but requires less careful attention, or at least permits more freedom of movement and adaptation to local conditions (fig. 39).

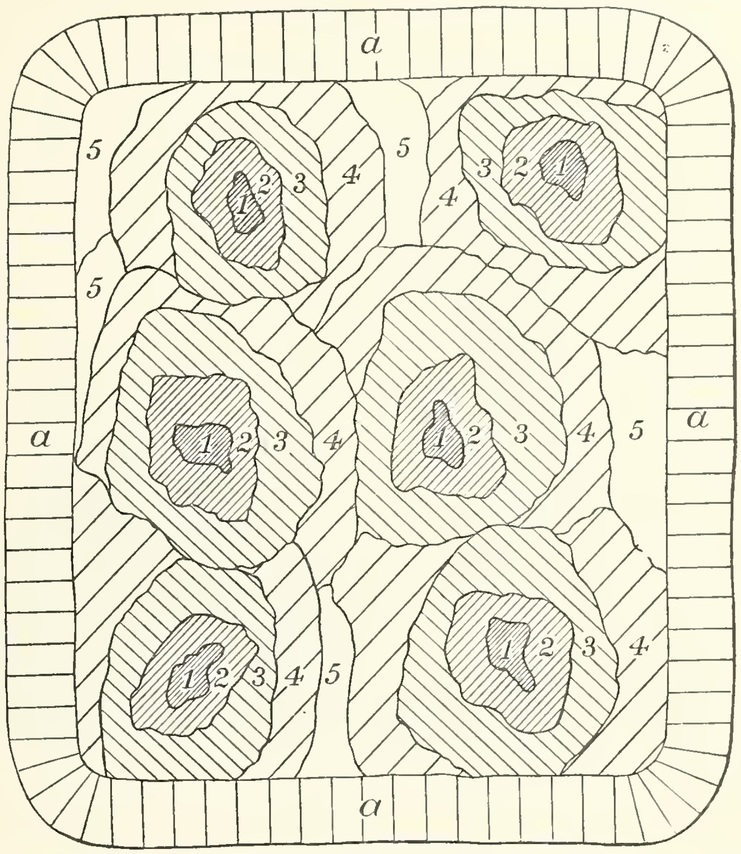


Fig. 39.—Showing plan of group system in regenerating a forest crop. 1, 2, 3, 4, successive groups of young timber, 1 being the oldest, 4 the youngest, 5 old timber; *a*, wind mantle, specially managed to secure protection.

It is especially adapted to mixed woods, as it permits securing for each species the most desirable light conditions by making the openings larger or smaller, according as the species we wish to favor in a particular group demand more or less shade. Further, when different species are ripe for regeneration at different times, this plan makes it possible to take them in hand as needed. Again, we can begin with one group or we can take in hand several groups simultaneously, as may be desirable and practicable.

We start our groups of new crop either where a young growth is already on the ground, enlarging around it, or where old timber has reached its highest usefulness and should be cut in order that we may not lose the larger growth which young trees would make; or else we choose a place which is but poorly stocked, where, if it is not regenerated, the soil is likely to deteriorate further. The choice is affected further by the consideration that dry situations should be taken in hand earlier than those in which the soil and site are more favorable, and that some species reach maturity and highest use value earlier than others and should therefore be reproduced earlier. In short, we begin the regeneration when and where the necessity for it exists, or where the young crop has the best chance to start most satisfactorily with the least artificial aid. Of course advantage should be taken of the occurrence of seed years, which come at different intervals with different species.

If we begin with a group of young growth already on the ground, our plan is to remove gradually the old trees standing over them when no longer required for shade, and then to cut away the adjoining old growth and enlarge the opening in successive narrow bands around the young growth. When the first band has seeded itself satisfactorily, and the young growth has come to require more light (which may take several years), we remove another band around it, and thus the regeneration progresses. Where no young growth already exists, of course the first opening is made to afford a start, and afterwards the enlargement follows as occasion requires.

SIZE OF OPENINGS.

The size of the openings and the rapidity with which they should be enlarged vary, of course, with local conditions and the species which is to be favored, the light-needing species requiring larger openings and quicker light additions than the shade-enduring. It is difficult to give any

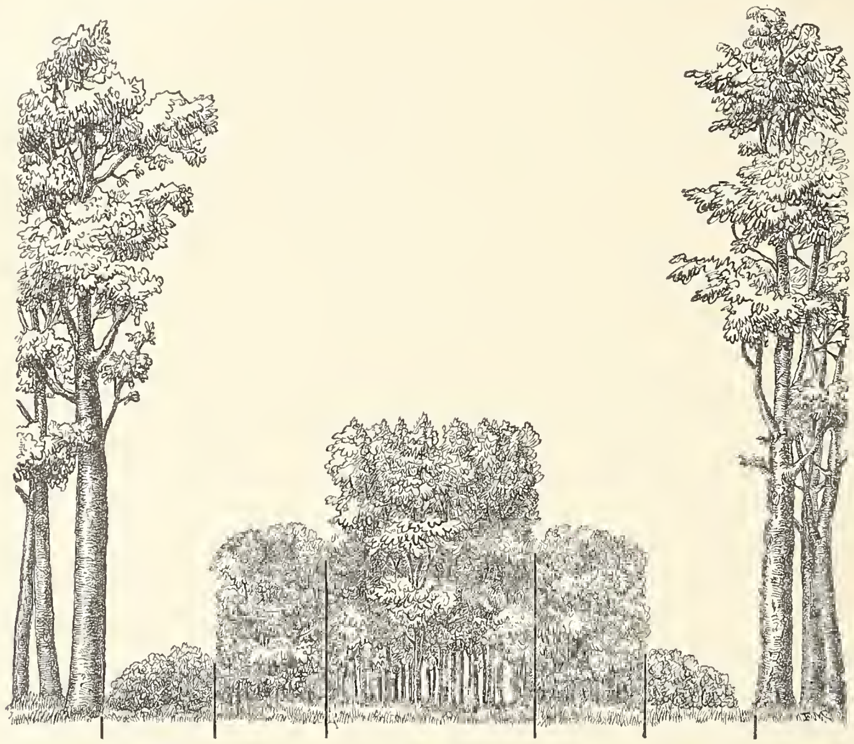


FIG. 40.—Appearance of regeneration by group method.

rules, since the modifications due to local conditions are so manifold, requiring observation and judgment. Caution in not opening too much at a time and too quickly may avoid failure in securing good stands.

In general, the first openings may contain from one-fourth to one-half an acre or more, and the gradual enlarging may progress by clearing bands of a breadth not to exceed the height of the surrounding timber.

The time of the year when the cutting is to be done is naturally in winter, when the farmer has the most leisure, and when the wood seasons best after felling and is also most readily moved. Since it is expected that the seed fallen in the autumn will sprout in the spring, all wood should, of course, be removed from the seed ground.

The first opening, as well as the enlargement of the groups, should not be made at once, but by gradual thinning out, if the soil is not in good condition to receive and germinate the seed and it is impracticable to put it in such condition by artificial means—hoeing or plowing.

It is, of course, quite practicable—nay, sometimes very desirable—to prepare the soil for the reception and germination of the seed. Where undesirable undergrowth has started it should be

cut out, and where the soil is deteriorated with weed growth or compacted by the tramping of cattle it should be hoed or otherwise scarified, so that the seed may find favorable conditions. To let pigs do the plowing and the covering of acorns is not an uncommon practice abroad.

It is also quite proper, if the reproduction from the seed of the surrounding mother trees does not progress satisfactorily, to assist, when an opportunity is afforded, by planting such desirable species as were or were not in the composition of the original crop.

It may require ten, twenty, or forty years or more to secure the reproduction of a wood lot in this way. A new growth, denser and better than the old, with timber of varying age, will be the result. The progress of the regeneration in groups is shown on the accompanying plan, the different shadings showing the successive additions of young crop, the darkest denoting the oldest parts, first regenerated. If we should make a section through any one of the groups, this, ideally represented, would be like fig. 40, the old growth on the outside, the youngest new crop adjoining it, and tiers of older growths of varying height toward the center of the group.

WIND MANTLE.

On the plan there will be noted a strip specially shaded surrounding the entire plat (fig. 39, *a*), representing a strip of timber which should surround the farmer's wood lot, and which he should keep as dense as possible, especially favoring undergrowth. This part, if practicable, should be kept reproduced as coppice or by the method of selection, i. e., by taking out trees here and there. When gaps are made, they should be filled, if possible, by introducing shade-enduring kinds, which, like the spruces and firs and beech, retain their branches down to the foot for a long time. This mantle is intended to protect the interior against the drying influence of winds, which are bound to enter the small wood lot and deteriorate the soil. The smaller the lot the more necessary and desirable it is to maintain such a protective cover or windbreak.

COPPICE.

Besides reproducing a wood crop from the seed of mother trees or by planting, there is another reproduction possible by sprouts from the stump. This, to be sure, can be done only with broad-leafed species, since conifers, with but few exceptions, do not sprout from the stump. When a wood lot is cut over and over again, the reproduction taking place by such sprouts we call "coppice."

Most wooded areas in the Eastern States have been so cut that reproduction from seed could not take place, and hence we have large areas of coppice, with very few seedling trees interspersed. As we have seen in the chapter on "How trees grow," the sprouts do not develop into as good trees as the seedlings. They grow faster, to be sure, in the beginning, but do not grow as tall and are apt to be shorter lived.

For the production of firewood, fence, and post material, coppice management may suffice, but not for dimension timber. And even to keep the coppice in good reproductive condition care should be taken to secure a certain proportion of seedling trees, since the old stumps, after repeated cutting, fail to sprout and die out.

Soil and climate influence the success of the coppice; shallow soils produce weaker but more numerous sprouts, and are more readily deteriorated by the repeated laying bare of the soil; a mild climate is most favorable to a continuance of the reproductive power of the stump.

Some species sprout more readily than others; hence the composition of the crop will change unless attention is paid to it. In the coppice, as in any other management of a natural wood crop, a desirable composition must first be secured, which is done by timely improvement cuttings, as described in a previous section.

The best trees for coppice in the Northeastern States are the chestnut, various oaks, hickory, ash, elm, maples, basswood, and black locust, which are all good sprouters.

When cutting is done for reproduction the time and manner are the main care. The best results are probably obtained, both financially and with regard to satisfactory reproduction, when the coppice is cut between the twentieth and thirtieth year. All cutting must be done in early spring or in winter, avoiding, however, days of severe frost, which is apt to sever the bark from the trunk and to kill the cambium. Cutting in summer kills the stump, as a rule. The cut should

be made slanting downward, and as smooth as possible, to prevent collection of moisture on the stump and the resulting decay, and as close as possible to the ground, where the stump is less exposed to injuries, and the new sprouts, starting close to the ground, may strike independent roots.

Fail places or gaps should be filled by planting. This can be readily done by bending to the ground some of the neighboring sprouts, when 2 to 3 years old, notching, fastening them down with a wooden hook or a stone, and covering them with soil a short distance (4 to 6 inches) from the end. The sprout will then strike root, and after a year or so may be severed from the mother stock by a sharp cut (fig. 41).

For the recuperation of the crop, it is desirable to maintain a supply of seedling trees, which may be secured either by the natural seeding of a few mother trees of the old crop which are left, or by planting. This kind of management, coppice with seedling or standard trees intermixed, if the latter are left regularly and well distributed over the wood lot, leads to a management called "standard coppice." In this it is attempted to avoid the drawbacks of the coppice, viz, failure to produce dimension material and running out of the stocks. The former object is, however, only partially accomplished, as the trees grown without sufficient side shading are apt to produce branchy boles and hence knotty timber, besides injuring the coppice by their shade.

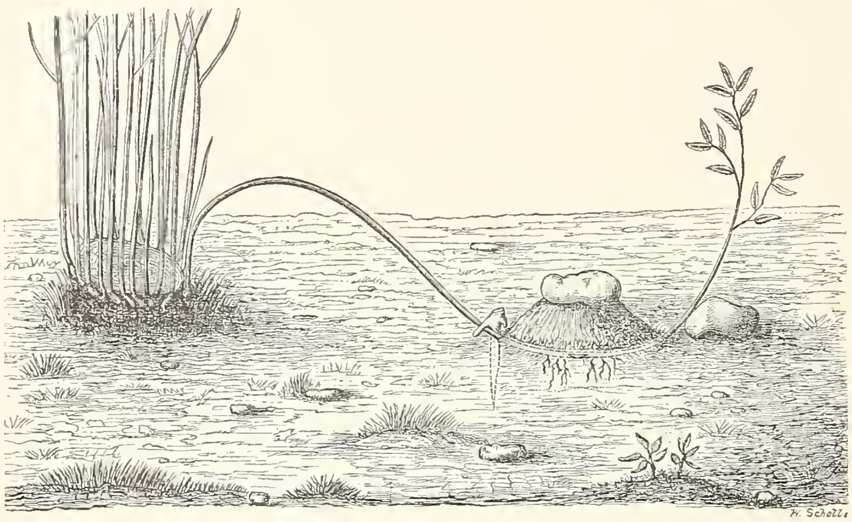


FIG. 41.—Method of layering to produce new stocks in coppice wood.

PLAN OF MANAGEMENT.

In order to harmonize the requirements of the wood lot from a sylvicultural point of view and the needs of the farmer for wood supplies, the cutting must follow some systematic plan.

The improvement cuttings need not, in point of time, have been made all over the lot before beginning the cuttings for regeneration, provided they have been made in those parts which are to be regenerated. Both the cuttings may go on simultaneously, and this enables the farmer to gauge the amount of cutting to his consumption. According to the amount of wood needed, one or more groups may be started at the same time. It is, however, desirable, for the sake of renewing the crop systematically, to arrange the groups in a regular order over the lot.

HOW TO CULTIVATE THE WOOD CROP.

Where only firewood is desired—i. e., wood without special form, size, or quality—no attention to the crop is necessary, except to insure that it covers the ground completely. Nevertheless, even in such a crop, which is usually managed as a coppice, some of the operations described in this chapter may prove advantageous. Where, however, not only quantity but useful quality of the crop is also to be secured the development of the wood crop may be advantageously influenced by controlling the supply of light available to the individual trees.

It may be proper to repeat here briefly what has been explained in previous pages regarding the influence of light on tree development.

EFFECT OF LIGHT ON WOOD PRODUCTION.

Dense shade preserves soil moisture, the most essential element for wood production; a close stand of suitable kinds of trees secures this shading and prevents the surface evaporation of soil moisture, making it available for wood production. But a close stand also cuts off side light and

confines the lateral growing space, and hence prevents the development of side branches and forces the growth energy of the soil to expend itself in height growth; the crown is carried up, and long, cylindrical shafts, clear of branches, are developed. A close stand thus secures desirable form and quality. Yet, since the quality of wood production or accretion (other things being equal) is in direct proportion to the amount of foliage and the available light, and since an open position promotes the development of a larger crown and of more foliage, an open stand tends to secure a larger amount of wood accretion on each tree. On the other hand, a tree grown in the open, besides producing more branches, deposits a larger proportion of wood at the base, so that the shape of the bole becomes more conical, a form which in sawing proves unprofitable; whereas a tree grown in the dense forest both lengthens its shaft at the expense of branch growth and makes a more even deposit of wood over the whole trunk, thus attaining a more cylindrical form. While, then, the total amount of wood production per acre may be as large in a close stand of trees as in an open one (within limits), the distribution of this amount among a larger or smaller number of individual trees produces different results in the quality of the crop. And since the size of a tree or log is important in determining its usefulness and value, the sooner the individual trees reach useful size, without suffering in other points of quality, the more profitable the whole crop.

NUMBER OF TREES PER ACRE.

The care of the forester, then, should be to maintain the smallest number of individuals on the ground which will secure the greatest amount of wood growth in the most desirable form of which the soil and climate are capable, without deteriorating the soil conditions. He tries to secure the most advantageous individual development of single trees without suffering the disadvantages resulting from too open stand. The solution of this problem requires the greatest skill and judgment, and rules can hardly be formulated with precision, since for every species or combination of species and conditions these rules must be modified.

In a well-established young crop the number of seedlings per acre varies greatly, from 3,000 to 100,000, according to soil, species, and the manner in which it originated, whether planted, sown, or seeded naturally.[1] Left to themselves, the seedlings, as they develop, begin to crowd each other. At first this crowding results only in increasing the height growth and in preventing the spread and full development of side branches; by and by the lower branches failing to receive sufficient light finally die and break off—the shaft "clears itself." Then a distinct development of definite crowns takes place, and after some years a difference of height growth in different individuals becomes marked. Not a few trees fail to reach the general upper crown surface, and being more or less overtopped, we can readily classify them according to height and development of crown, the superior or "dominating" ones growing more and more vigorously, the inferior or "dominated" trees falling more and more behind, and finally dying for lack of light, and thus a natural reduction in numbers, or thinning, takes place. This natural thinning goes on with varying rates at different ages, continuing through the entire life of the crop; so that, while only 4,000 trees per acre may be required in the tenth year to make a dense crown cover or normally close stand, untouched by man, in the fortieth year 1,200 would suffice to make the same dense cover, in the eightieth year 350 would be a full stand, and in the one hundredth not more than 250, according to soil and species, more or less. As we can discern three stages in the development of a single tree—the juvenile, adolescent, and mature—so, in the development of a forest growth, we may distinguish three corresponding stages, namely, the "thicket" or brushwood, the "pole-wood" or sapling, and the "timber" stage. During the thicket stage, in which the trees have a bushy appearance, allowing hardly any distinction of stem and crown, the height growth is most rapid. This period may last, according to conditions and species, from five or ten to thirty and even forty years—longer on poor soils and with shade-enduring species, shorter with light-needing species on good soils—and, while it lasts, it is in the interest of the wood grower to maintain the close stand, which produces the long shaft, clear of branches, on which at a later period the wood that makes valuable clear timber may accumulate. Form development is now most important. The lower branches are to die and break off before they become too large. With light-needing species and

[1] If the crop does not, at 3 to 5 years of age, shade the ground well, with a complete crown cover or canopy, it can not be said to be well established and should be filled out by planting.

with deciduous trees generally this dying off is accomplished more easily than with conifers. The spruces and even the white pine require very dense shading to "clear" the shaft. During this period it is only necessary to weed out the undesirable kinds, such as trees infested by insect and fungus, shrubs, sickly, stunted, or bushy trees which are apt to overtop and prevent the development of their better neighbors. In short, our attention is now devoted mainly to improving the composition of the crop.

WEEDING AND CLEANING THE CROP.

This weeding or cleaning is easily done with shears when the crop is from 3 to 5 years old. Later, mere cutting back of the undesirable trees with a knife or hatchet may be practiced. In well-made artificial plantations this weeding is rarely needed until about the eighth or tenth year. But in natural growths the young crop is sometimes so dense as to inordinately interfere with the development of the individual trees. The stems then remain so slender that there is danger of their being bent or broken by storm or snow when the growth is thinned out later. In such cases timely thinning is indicated to stimulate more rapid development of the rest of the crop. This can be done most cheaply by cutting swaths or lanes 1 yard wide and as far apart through the crop, leaving strips standing. The outer trees of the strip, at least, will then shoot ahead and become the main crop. These weeding or improvement cuttings, which must be made gradually and be repeated every two or three years, are best performed during the summer months, or in August and September, when it is easy to judge what should be taken out.

METHODS OF THINNING.

During the "thicket" stage, then, which may last from 10 to 25 and more years, the crop is gradually brought into proper composition and condition. When the "pole-wood" stage is reached, most of the saplings being now from 3 to 6 inches in diameter and from 15 to 25 feet in height, the variation in sizes and in appearance becomes more and more marked. Some of the taller trees begin to show a long, clear shaft and a definite crown. The trees can be more or less readily classified into height and size classes. The rate at which the height growth has progressed begins to fall off and diameter growth increases. Now comes the time when attention must be given to increasing this diameter growth by reducing the number of individuals, and thus having all the wood which the soil can produce deposited on fewer individuals. This is done by judicious and often repeated thinning, taking out some of the trees, and thereby giving more light and increasing the foliage of those remaining; and as the crowns expand, so do the trunks increase their diameter in direct proportion. These thinnings must, however, be made cautiously lest at the same time the soil is exposed too much, or the branch growth of those trees which are to become timber wood is too much stimulated. So varying are the conditions to be considered, according to soil, site, species, and development of the crop, that it is well-nigh impossible, without a long and detailed discussion, to lay down rules for the proper procedure. In addition the opinions of authorities differ largely both as to manner and degree of thinning, the old school advising moderate and the new school severer thinnings.

For the farmer, who can give personal attention to detail and whose object is to grow a variety of sizes and kinds of wood, the following general method may perhaps be most useful.

First determine which trees are to be treated as the main crop or "final-harvest" crop. For this, 300 to 500 trees per acre of the best grown and most useful kinds may be selected, which should be distributed as uniformly as possible over the acre. These, then—or as many as may live till the final harvest—are destined to grow into timber and are to form the special favorites as much as possible. They may at first be marked to insure recognition; later on they will be readily distinguished by their superior development. The rest, which we will call the "subordinate" crop, is then to serve merely as filler, nurse, and soil cover.

WHAT TREES TO REMOVE.

It is now necessary, by careful observation of the surroundings of each of the "final-harvest" crop trees, or "superiors," as we may call them, to determine what trees of the "subordinate" crop trees, or "inferiors," must be removed. All nurse trees that threaten to overtop the superiors

must either be cut out or cut back and topped, if that is practicable, so that the crown of the superiors can develop freely. Those that are only narrowing in the superiors from the side, without preventing their free top development, need not be interfered with, especially while they are still useful in preventing the formation and spreading of side branches on the superiors. As soon as the latter have fully cleared their shafts, these crowding inferiors must be removed. Care must be taken, however, not to remove too many at a time, thus opening the crown cover too severely and thereby exposing the soil to the drying influence of the sun. Gradually, as the crowns of inferiors standing farther away begin to interfere with those of the superiors, the inferiors are removed, and thus the full effect of the light is secured in the accretion of the main harvest crop; at the same time the branch growth has been prèvented and the soil has been kept shaded. Meanwhile thinnings may also be made in the subordinate crop, in order to secure also the most material from this part of the crop. This is done by cutting out all trees that threaten to be killed by their neighbors. In this way many a useful stick is saved and the dead material, only good for firewood, lessened. It is evident that trees which in the struggle for existence have fallen behind, so as to be overtopped by their neighbors, can not, either by their presence or by their removal, influence the remaining growth. They are removed only in order to utilize their wood before it decays.

It may be well to remark again that an undergrowth of woody plants interferes in no way with the devolopment of the main crop; on the contrary, aids by its shade in preserving favorable moisture conditions. Its existence, however, shows in most cases that the crown cover is not as dense as it should be, and hence that thinning is not required. Grass and weed growth, on the other hand, is emphatically disadvantageous and shows that the crown cover is dangerously open.

The answer to the three questions, when to begin the thinnings, how severely to thin, and how often to repeat the operation, must always depend upon the varying appearance of the growth and the necessities in each case. The first necessity for interference may arise with light-needing species as early as the twelfth or fifteenth year; with shade-enduring, not before the twentieth or twenty-fifth year. The necessary severity of the thinning and the repetition are somewhat interdependent. It is better to thin carefully and repeat the operation oftener than to open up so severely at once as to jeopardize the soil conditions. Especially in younger growths and on poorer soil, it is best never to open a continuous crown cover so that it could not close up again within three to five years; rather repeat the operation oftener. Later, when the trees have attained heights of 50 to 60 feet and clear boles (which may be in forty to fifty years, according to soil and kind) the thinning may be more severe, so as to require repetition only every six to ten years.

The condition of the crown cover, then, is the criterion which directs the ax. As soon as the crowns again touch or interlace the time has arrived to thin again. In mixed growths it must not be overlooked that light-needing species must be specially protected against shadier neighbors. Shade-enduring trees, such as the spruces, beech, sugar maple, and hickories, bear overtopping for a time and will then grow vigorously when more light is given, while light-needing species, like the pines, larch, oaks, and ash, when once suppressed, may never be able to recover.

Particular attention is called to the necessity of leaving a rather denser "wind mantle" all around small groves. In this part of the grove the thinning must be less severe, unless coniferous trees on the outside can be encouraged by severe thinning to hold their branches low down, thus increasing their value as windbreaks.

The thinnings, then, while giving to the "final-harvest" crop all the advantage of light for promoting its rapid development into serviceable timber size, furnish also better material from the subordinate crop. At 60 to 70 years of age the latter may have been entirely removed and only the originally selected "superiors" remain on the ground, or as many of them as have not died and been removed; 250 to 400 of these per acre will make a perfect stand of most valuable form and size, ready for the final harvest, which should be made as indicated in the preceding chapter.

The Relation of Forests to Farms.

That all things in nature are related to each other and interdependent is a common saying, a fact doubted by nobody, yet often forgotten or neglected in practical life. The reason is partly indifference and partly ignorance as to the actual nature of the relationship; hence we suffer, deservedly or not.

The farmer's business, more than any other perhaps, depends for its success upon a true estimate of and careful regard for this interrelation. He adapts his crop to the nature of the soil, the manner of its cultivation to the changes of the seasons, and altogether he shapes conditions and places them in their proper relations to each other and adapts himself to them.

Soil, moisture, and heat are the three factors which, if properly related and utilized, combine to produce his crops. In some directions he can control these factors more or less readily; in others they are withdrawn from his immediate influence, and he is seemingly helpless. He can maintain the fertility of the soil by manuring, by proper rotation of crops, and by deep culture; he can remove surplus moisture by ditching and draining; he can, by irrigation systems, bring water to his crops, and by timely cultivation prevent excessive evaporation, thereby rendering more water available to the crop; but he can not control the rainfall nor the temperature changes of the seasons. Recent attempts to control the rainfall by direct means exhibit one of the greatest follies and misconceptions of natural forces we have witnessed during this age. Nevertheless, by indirect means the farmer has it in his power to exercise much greater control over these forces than he has attempted hitherto. He can prevent or reduce the unfavorable effects of temperature changes; he can increase the available water supplies, and prevent the evil effects of excessive rainfall; he can so manage the waters which fall as to get the most benefit from them and avoid the harm which they are able to inflict.

Before attempting to control the rainfall itself by artifice, we should study how to secure the best use of that which falls as it comes within reach of human agencies and becomes available by natural causes.

How poorly we understand the use of these water supplies is evidenced yearly by destructive freshets and floods, with the accompanying washing of soil, followed by droughts, low waters, and deterioration of agricultural lands. It is claimed that annually in the United States about 200 square miles of fertile soil are washed into brooks and rivers, a loss of soil capital which can not be repaired for centuries. At the same time millions of dollars are appropriated yearly in the river and harbor bills to dig out the lost farms from the rivers, and many thousands of dollars' worth of crops and other property are destroyed by floods and overflows; not to count the large loss from droughts which this country suffers yearly in one part or the other, and which, undoubtedly, could be largely avoided, if we knew how to manage the available water supplies.

The regulation, proper distribution, and utilization of the rain waters in humid as well as in arid regions—water management—is to be the great problem of successful agriculture in the future.

One of the most powerful means for such water management lies in the proper distribution and maintenance of forest areas. Nay, we can say that the most successful water management is not possible without forest management.

THE FOREST WATERS THE FARM.

Whether forests increase the amount of precipitation within or near their limits is still an open question, although there are indications that under certain conditions large, dense forest areas may have such an effect. At any rate, the water transpired by the foliage is certain, in some degree, to increase the relative humidity near the forest, and thereby increase directly or indirectly the water supplies in its neighborhood. This much we can assert, also, that while extended plains and fields, heated by the sun, and hence giving rise to warm currents of air, have the tendency to prevent condensation of the passing moisture-bearing currents, forest areas, with their cooler, moister air strata, do not have such a tendency, and local showers may therefore become more frequent in their neighborhood. But, though no increase in the amount of rainfall may be secured by forest areas, the availability of whatever falls is increased for the locality by a well-kept and properly located forest growth. The foliage, twigs, and branches break the fall of the raindrops, and so does the litter of the forest floor; hence the soil under this cover is not compacted as in the open field, but kept loose and granular, so that the water can readily penetrate and percolate. The water thus reaches the ground more slowly, dripping gradually from the leaves, branches, and trunks, and allowing more time for it to sink into the soil. This percolation is also made easier by the channels along the many roots. Similarly, on account of the open structure of the soil and the slower melting of the snow under a forest cover in spring, where it

lies a fortnight to a month longer than in exposed positions and melts with less waste from evaporation, the snow waters more fully penetrate the ground. Again, more snow is caught and preserved under the forest cover than on the wind-swept fields and prairies.

All these conditions operate together, with the result that larger amounts of the water sink into the forest soil and to greater depths than in open fields. This moisture is conserved because of the reduced evaporation in the cool and still forest air, being protected from the two great moisture-dissipating agents, sun and wind. By these conditions alone the water supplies available in the soil are increased from 50 to 60 per cent over those available on the open field. Owing to these two causes, then—increased percolation and decreased evaporation—larger amounts of moisture become available to feed the springs and subsoil waters, and these become finally available to the farm, if the forest is located at a higher elevation than the field. The great importance of the subsoil water especially and the influence of forest areas upon it has so far received too little attention and appreciation. It is the subsoil water that is capable of supplying the needed moisture in times of drought.

THE FOREST TEMPERS THE FARM.

Another method by which a forest belt becomes a conservator of moisture lies in its wind-breaking capacity, by which both velocity and temperature of winds are modified and evaporation from the fields to the leeward is reduced.

On the prairie, wind swept every day and every hour, the farmer has learned to plant a wind-break around his buildings and orchards, often only a single row of trees, and finds even that a desirable shelter, tempering both the hot winds of summer and the cold blasts of winter. The fields he usually leaves unprotected; yet a wind-break around his crops to the windward would bring him increased yield, and a timber belt would act still more effectively. Says a farmer from Illinois:

> My experience is that now in cold and stormy winters fields protected by timber belts yield full crops, while fields not protected yield only one-third of a crop. Twenty-five or thirty years ago we never had any wheat killed by winter frost, and every year we had a full crop of peaches, which is now very rare. At that time we had plenty of timber around our fields and orchards, now cleared away.

Not only is the temperature of the winds modified by passing over and through the shaded and cooler spaces of protecting timber belts disposed toward the windward and alternating with the fields, but their velocity is broken and moderated, and since with reduced velocity the evaporative power of the winds is very greatly reduced, so more water is left available for crops. Every foot in height of a forest growth will protect 1 rod in distance, and several belts in succession would probably greatly increase the effective distance. By preventing deep freezing of the soil the winter cold is not so much prolonged, and the frequent fogs and mists that hover near forest areas prevent many frosts. That stock will thrive better where it can find protection from the cold blasts of winter and from the heat of the sun in summer is a well-established fact.

THE FOREST PROTECTS THE FARM.

On the sandy plains, where the winds are apt to blow the sand, shifting it hither and thither, a forest belt to the windward is the only means to keep the farm protected.

In the mountain and hill country the farms are apt to suffer from heavy rains washing away the soil. Where the tops and slopes are bared of their forest cover, the litter of the forest floor burnt up, the soil trampled and compacted by cattle and by the patter of the raindrops, the water can not penetrate the soil readily, but is carried off superficially, especially when the soil is of clay and naturally compact. As a result the waters, rushing over the surface down the hill, run together in rivulets and streams and acquire such a force as to be able to move loose particles and even stones; the ground becomes furrowed with gullies and runs; the fertile soil is washed away; the fields below are covered with silt; the roads are damaged; the water courses tear their banks, and later run dry, because the waters that should feed them by subterranean channels have been carried away in the flood.

The forest cover on the hilltops and steep hillsides which are not fit for cultivation prevents this erosive action of the waters by the same influence by which it increases available water supplies. The important effects of a forest cover, then, are retention of larger quantities of water

and carrying them off under ground and giving them up gradually, thus extending the time of their usefulness and preventing their destructive action.

In order to be thoroughly effective, the forest growth must be dense, and, especially, the forest floor must not be robbed of its accumulations of foliage, surface mulch, and litter, or its underbrush by fire, nor must it be compacted by the trampling of cattle.

On the gentler slopes, which are devoted to cultivation, methods of underdraining, such as horizontal ditches partly filled with stones and covered with soil, terracing, and contour plowing, deep cultivation, sodding, and proper rotation of crops must be employed to prevent damage from surface waters.

THE FOREST SUPPLIES THE FARM WITH USEFUL MATERIAL.

All the benefits derived from the favorable influence of forest belts upon water conditions can be had without losing any of the useful material that the forest produces. The forest grows to be cut and to be utilized; it is a crop to be harvested. It is a crop which, if properly managed, does not need to be replanted; it reproduces itself.

When once established, the ax, if properly guided by skillful hands, is the only tool necessary to cultivate it and to reproduce it. There is no necessity of planting unless the wood lot has been mismanaged.

The wood lot, then, if properly managed, is not only the guardian of the farm, but it is the savings bank from which fair interest can be annually drawn, utilizing for the purpose the poorest part of the farm. Nor does the wood lot require much attention; it is to the farm what the workbasket is to the good housewife—a means with which to improve the odds and ends of time, especially during the winter, when other farm business is at a standstill.

It may be added that the material which the farmer can secure from the wood lot, besides the other advantages recited above, is of far greater importance and value than is generally admitted.

On a well-regulated farm of 160 acres, with its 4 miles and more of fencing and with its wood fires in range and stove, at least 25 cords of wood are required annually, besides material for repair of buildings, or altogether the annual product of probably 40 to 50 acres of well-stocked forest is needed. The product may represent, according to location, an actual stumpage value of from $1 to $3 per acre, a sure crop coming every year without regard to weather, without trouble and work, and raised on the poorest part of the farm. It is questionable whether such net results could be secured with the same steadiness from any other crop. Nor must it be overlooked that the work in harvesting this crop falls into a time when little else could be done.

Wire fences and coal fires are, no doubt, good substitutes, but they require ready cash, and often the distance of haulage makes them rather expensive. Presently, too, when the virgin woods have been still further culled of their valuable stores, the farmer who has preserved a sufficiently large and well-tended wood lot will be able to derive a comfortable money revenue from it by supplying the market with wood of various kinds and sizes. The German State forests, with their complicated administrations, which eat up 4 per cent of the gross income, yield, with prices of wood about the same as in our country, an annual net revenue of from $1 to $4 and more per acre. Why should not the farmer, who does not pay salaries to managers, overseers, and forest guards, make at least as much money out of this crop when he is within reach of a market?

With varying conditions the methods would of course vary. In a general way, if he happens to have a virgin growth of mixed woods, the first care would be to improve the composition of the wood lot by cutting out the less desirable kinds, the weeds of tree growth, and the poorly grown trees which impede the development of more deserving neighbors.

The wood thus cut he will use as firewood or in any other way, and even if he could not use it at all and had to burn it up the operation would pay indirectly by leaving him a better crop. Then he may use the rest of the crop, gradually cutting the trees as needed, but he must take care that the openings are not made too large, so that they can readily fill out with young growth from the seed of the remaining trees, and he must also pay attention to the young aftergrowth, giving it light as needed. Thus without ever resorting to planting he may harvest the old timber and have a new crop taking its place and perpetuate the wood lot without in any way curtailing his use of the same.

G. PRINCIPLES OF FOREST ECONOMY.

It is possible to carry on forest production, to grow and market forest products, without making a special business of it.

The farmer can manage his wood lot so as to produce and reproduce a valuable wood crop, applying all the art of silviculture without any special bookkeeping or other business organization. If he performs his own labor and counts it nothing, and if he use his own wood crop in his buildings, fences, or in his stove, or can sell it to his neighbors, and if he keep his wood lot on the rocky part of his farm or where it serves as protection against damage from winds or waters, he can make forest growing at least indirectly profitable without much effort.

The case is different when we go into forest growing as a business for the market and for revenue, for profit on an invested capital, and on expenditures. Then it becomes necessary to adopt more systematic procedures, to organize, as in a large mercantile establishment, the business in detail, to adopt proper methods of bookkeeping, to keep control of income and outgo, so as to insure the profitable running of the business; and, as in all properly conducted business enterprises, the adequacy of the capital employed and of the margin realized must enter into consideration.

Besides the purely technical care of the productive forces to secure the best quantitative and qualitative production of material—the highest "gross" yield—there must be exercised a managerial care to secure the most favorable relations of expenditure and income, the highest "net" yield, a surplus of money results without which the industry would appear purposeless, at least from the standpoint of private enterprise and investment.

Carried on by government activity for reasons of general cultural advantages, the "net yield" or money profits may be considered secondary, perhaps be dispensed with, and it may even appear rational to carry on this industry like any other form of public works, at a loss. Nevertheless, even in that case, it would be desirable to organize and systematically carry on the business, to keep account, compare, and bring into relation the results with the efforts; to measure the cost.

The manner in which such systematic business organization and accounting is done must vary according to the conditions and peculiarities of the industry, and hence it differs widely in the different industries. Thus, although agriculture and forestry, both having to do with productions of the soil, would appear of similar nature, yet the conditions of production vary so widely that their methods and problems of management and of accounting must also differ considerably.

In both these industries there is required a fixed and a working capital; but while the agriculturist has this outside of land and houses, in movable condition, or can in a short time—at the end of each season—make most of it movable, the forest manager has his working capital mostly bound up, immovable, represented in the growing timber, the accumulation of many years' growth, which may or may not be ready for harvest.

The length of time with which forestry has to calculate in the creation of its products is an element which introduces problems into the calculation of future yields, both gross and net, unknown to most other industries and difficult to solve. A further difficulty, also peculiar to the industry, is the fact that it can not be readily determined what part of the forest ought to be left as working capital and what part should be harvested; there is no definite time, naturally determined, when the harvest is ready, and the question as to which part of the growing timber should be left standing for further accumulation of products to be harvested involves complicated technical as well as financial and managerial considerations.

Furthermore, there are difficulties arising from the manner in which forest growth develops, in estimating or determining the accretions in quantity and value of the crop, and difficulties in

determining the value of forest soil and in predicting the market value of the products at future times when they will be ready for harvest.

All these difficulties, which are peculiar to the forestry business, at least to a much greater degree than to any other business, require much more careful planning and systematic procedure than is usually necessary with other industries in which the product is sold or expected to be turned to account within a short time from its production and in which the cost of production and the price of products can be more readily ascertained, the methods of carrying on the business more readily changed or adapted to changing market conditions, and the fixed capital more readily liquidated.

This branch of the forestry business, therefore, in countries where the industry is developed, has experienced very elaborate treatment, the purely economic or managerial problems—forest economy or forest management—being sharply distinguished from the problems of technical forest production, forestry technique. While this latter branch deals with the questions of silviculture, forest protection, and forest utilization—how to grow, protect, and use to best advantage the forest products—the former, forest economy, deals with the questions of forest valuation, forestal statics, and forest regulation, how to determine the quantity of production, how to compare expenditure and result, how to dispose of the forces of production, regulate orderly, and systematically manage the forest property so as to produce continuously the most satisfactory money results.

We speak now, it must not be forgotten, not of the business of chopping down and turning into cash virgin forest growth, a mere crude exploitation of the natural forest resources in which the present lumber industry is concerned, but we propose to outline the considerations which are needful when we desire to engage in the business of producing the supplies for the lumber industry after virgin supplies are exhausted, an industry which so far has remained undeveloped in the United States. In the lumber industry of to-day the business methods, as far as the accounting of forest supplies are concerned, are of the crudest. It consists in ascertaining roughly the amount of timber[1] which could at once be readily utilized with profit, and no account is made of any future values, or rarely so.

The forest is treated like a quarry or mine from which the pay ore is removed, then to be abandoned. If there should be anything of value left or developed later, this is worked out in the same way, like working over the dump of an abandoned mine. In other words, the lumber industry is not a productive but a transformative industry, preparing the product for market; it st nds in relation to the forestry industry as that of the cattle breeder to that of the butcher, and wood production is not a part of it.

The lumbering industry, concerned in the utilization of forest products, is only the tail end of the forestry industry, which latter begins with the systematic management of the forest resources for reproduction and continued revenue.

In the forestry business we consider the forest somewhat like an orchard from which we only reap the fruit annually, or like a herd of cattle kept for breeding purposes when we may slaughter the old but look for a constant supply of young cattle, growing and maintaining a due proportion of calves and heifers. Thus the forester proposes to use annually or periodically only as much as has annually or periodically grown. If, for instance, he had found that on his 1,000 acres the average annual wood production was 50 cubic feet per acre he would be entitled to cut $50 \times 1,000 = 50,000$ cubic feet yearly.

In order to produce this amount continuously and in such form and size as to be useful, and to permit a harvesting every year, there would have to be a certain amount of wood stored up and distributed over younger and older trees or stands of trees, which are maintained as stock

[1] The ascertainment of the amount of standing timber is done in various ways. Usually the judgment of a more or less experienced expert, a "timber looker," is taken, who by riding or walking through the woods mentally forms an idea of the number of logs that could be got from the land, and of the cost of moving them to the mill. An improvement consists in making at least a few trial measurements either of the contents of average acres, or else counting and measuring the trees of certain kinds which constitute the main value. This is done especially with walnut, cherry, or yellow poplar, and other kinds which are especially valuable and occur scattered through the woods; these are now often sold by the tree instead of by the acre or by the M feet B. M.

A fair method also practiced is to sell by the "scaling" when the logs are cut and collected on "skidways," where they are measured and paid for by the M feet B. M.

on which the annual growth takes place (the wood capital), just as in the herd a certain number of cows and bulls and heifers of various ages must be kept to secure a continuous supply of cattle and a tolerably uniform revenue on the investment.

In order to be able to determine what this wood capital is to be and how much the yield or revenue that can be expected the manager must have knowledge of the manner and rapidity with which the crop develops.

It is not necessary to go into details of the methods developed to ascertain the amount of wood growing per acre at different ages, or how to determine the rate of g owth and the quantitative as well as qualitative accretion. It will, however, be needful to indicate briefly what in general the results of such measurements would be in order to get an insight as to how these will influence the methods of management.

While individual trees of the same species may develop very differently and seemingly without law, when we deal with larger numbers under forest conditions we may more readily discern that a more or less precise law and rate of growth can be established for each species and condition. Of course different soil and climatic conditions and the character of the site influence the rate of development of forest growth, yet on all sites the relative rate at various periods remains more or less constant.

Thus for a given species and site we will be able to discern after a brief seeding stage a juvenile stage, when trees develop in height growth at the expense of diameter growth; an adolescent stage, when height growth decreases and diameter growth accelerates, and a mature stage, when height growth practically ceases and diameter growth, although persisting, declines. The growth in volume progresses differently because the very wide rings or layers which are laid on in early life, and which denote rapid diameter growth, cover only a small circumference, while the much narrower ring of a later period laid on over a much thicker stem represents a much larger volume.

Thus the rate of growth in white pine decreases in height and thickness practically from the polewood stage forward, while the rate of growth in volume increases up to the sixtieth or eightieth year, and then continues uniformly for a century or more before it declines.

Or to illustrate in figures, a white pine seedling only 1 foot high and one-half inch in diameter, with hardly an appreciable volume of stem, will have reached a height of 30 feet in twenty years, 60 feet in forty years, 100 feet in one hundred years; the width of the rings will have averaged one-eighth to one-sixth inch during the first thirty years, while at one hundred years the average will have come down to one-twelfth inch; but the volume growth, which during the first thirty years was but a fraction of a cubic foot, has after sixty years attained a rate of 1 to 2 cubic feet per year, and is kept at that rate to a great age—two hundred and fifty to three hundred years.

If we substitute the red or Norway pine we will find the progress quite different. It may start out at about the same rate as the white pine, and at sixty years may also have attained a rate of 2 cubic feet per year, but soon the rate begins to decline, and in the one hundred and twentieth year with a volume of 80 cubic feet the average accretion is only two-thirds cubic foot per year. Its average growth for the one hundred and twenty years has now become equal to the current rate of growth.

The tree then passes its maximum capacity of wood production, for from this time on its current growth falls behind its average, and from the standpoint of quantitative production the tree should now be cut.

But there is a growth in value which does not progress continuously and proportionately with the growth in volume, and which is also an important factor in deciding when a tree is to be cut.

Generally in all lumber and timber markets the prices are classified, and sticks, boards, etc., are priced according to size as well as freedom from defects and knots. For instance, poplar logs under 12 inches may have no price at all, logs of 16 to 20 inches may bring $15, those of 20 to 29 inches may bring $20, and if over 30 inches $25 may be paid per 1,000 feet B. M. contained in the log. Hence, although the quantitative development may have decreased in the log of 29 inches, it may still pay to hold it over until the better-paying size is attained.

In a stand of trees, an acre of forest growth, the progress of wood production is, to be sure, different from that in the individual tree, for here the amount of wood to the acre at any time depends on the number of trees as well as their volume. And this number, as we have seen, rapidly decreases as the trees grow older and crowd each other, when some are killed and eliminated from taking part in the total wood production, while the remaining, with the increase in light and food supplies, increase their production. This increase in the rate of volume growth per acre is very rapid in young woods and on good soil; it reaches a maximum and then declines more or less rapidly according to species and site, very much according to the diameter growth of the individual.

The question as to the number of trees which should be allowed to grow per acre, so as to produce not only the largest amount of wood, but of useful sizes and best quality, which means freedom from knots and technically most serviceable in form and grain, is one of the foremost problems of both the technicist and the manager.

The capacity of our unmanaged virgin forests in this respect is no criterion of the possibilities, and on the other hand the experience of other countries is only partially applicable to our conditions. But as an example of what our white pine forests, for instance, may eventually produce, we may cite the experience with spruce in Germany, which on good soil is capable of producing at the rate of 40 cubic feet per acre each year during the first decade, as much as 120 cubic feet in the second decade, and at the rate of 200 cubic feet at the age of 40, while at one hundred and fifty it shows only an average of 80 cubic feet per acre annually; having declined from about the seventieth year on.

On poorer soils about one-half of this production may be expected, and if we inquire into the total quantity per acre we may find at thirty years 4,200 cubic feet of wood, more than twice that amount at sixty years, and 14,000 cubic feet at one hundred years, which appears an enormous yield compared to those of our virgin forests, whose yield is depressed by the presence of much valueless material and lack of density, and which would in double the time hardly have produced such amount. With other species, to be sure, entirely different aggregate amounts would result, but in general the march of progress would be in a similar proportion.

If, however, we have to deal not with seedling trees, but with coppice growth like the sprout lands of our New England States, the progress is entirely different. There are several million acres of hard-wood coppice in these States, which, when fairly stocked, produce annually for the first twenty-five to thirty years at the rate of a cord or a little less (i. e., about 100 cubic feet solid) per acre, but after that time very rapidly decline in production without an equivalent value increase, and hence must be cut when the maximum amount of wood production has been attained; this is also necessary from silvicultural reasons, as the stocks, if left too long, are impaired in reproductive power.

To be sure, such woods yield hardly any other material than firewood and fence rails. There are many trees to the acre, 1,500 to 2,000 at least, but each one is small, not more than 10 to 12 inches in diameter at best, hence the supply of firewood is in excess of the home demand and the price obtained hardly covers the expense of getting the material to market.

To produce materials of size and quality such as we now require in the lumber market, nature has taken from one hundred and fifty to five hundred years, and for the giants of the Pacific, two thousand years and more. Even with the best skill in managing the crop, not less than seventy-five to one hundred years from the seed will be required to produce logs fit for the mill, such as are now considered hardly worth sawing.

From such measurements and considerations of the quantitative and qualitative development of the crop, the economist will learn that the time at which a forest growth is utilized has an important bearing on the more or less intensive and profitable use of the resource.

When the crop, accumulated during a longer or shorter period, is ripe for the ax depends not only upon silvicultural and forest-technical considerations influenced by soil and climatic conditions and the species composing the forest, but, from a business point of view, upon market conditions and financial considerations. The material would hardly be useful for anything but firewood or small posts and fencing material at best before twenty years, and again for lumber or purposes of construction it may be considered fit for use not before one hundred and more years.

Market conditions may be such that the small demand for the first-mentioned class of products would make it unprofitable to cut the growth, and again while, other things being equal, the larger dimensions are not only more valuable and in greater demand, but permit a greater and greater intensity of exploitation,[1] yet the long time during which the capital represented in the standing timber is tied up, and must therefore produce at compound interest, may have a disadvantageous influence upon the balance sheet.

The determination, therefore, of the length of time during which the growth is to be allowed to accumulate, which is called rotation, requires not only consideration by the technicist, but very close and complicated calculations by the manager. According to the point of view from which this period of rotation is determined, we can distinguish and designate these time periods by various names which explain themselves, namely, as silvicultural rotation, rotation of greatest material production, financial rotation of highest harvest value, rotation of highest forest revenue, etc.[2]

Now, if an owner of land should stock it all with forest growth at the same time, he would have to wait twenty, forty, sixty, one hundred years or more, according to the rotation which he has recognized as most desirable, before he would have any returns, or else, if he should have a tract of virgin growth, all ripe for the ax, and cut it all, he would again have to wait many decades without income until the new growth can be profitably cut.

Such an intermittent revenue is not only undesirable for private enterprise, but also impracticable, since the cost of caring for the property would have to be provided for without any direct income during a long period.

For small holdings, such as the wood lot of a farmer, attached to the farm and readily supervised by him while attending to his regular business, the objection to the intermission of revenue is not serious altogether he manages his wood lot mainly for his own use. But in growing wood crops for the market as a business it is necessary to change the intermittent into an annual revenue, or at least one returning in short periods.

This is done by gradually bringing the forest into such condition that each year, or at least during each short period of the rotation, a portion or parcel, as nearly as possible producing the same amount of material or revenue, becomes ready for the harvest, until finally the whole forest area assumes the condition of what may be called the normal forest, or at least a regulated forest

Ideally such a forest when so regulated would yield every year or short period of years the same amount of material and approximately the same money revenue, the amount to be cut annually or periodically being as nearly as possible the amount annually growing.

If, for instance, we have a pine forest which we propose to manage under a rotation of one hundred years, which means that we expect to return for a new crop within one hundred years to the same acre we have just cut, and finding from our measurements that all our acres are of a uniformly producing capacity, we would have it divided into 100 equally large compartments, each stocked with trees just one year older than the preceding, and successfully representing 100 age classes, so that we could cut each year one compartment with the same amount of wood just one hundred years old.

[1] How, with the increase in the size of the log, the amount of lumber that can be obtained from it increases or the necessary waste decreases disproportionately may be seen from the subjoined table of output, based upon the results of the average sawmill practice:

Diameter of log (10 feet long)—	Real contents of log in feet, B. M. or one-twelfth cubic foot, allowing no waste.	Contents in feet B. M. as per Scribner or Doyle's rules.	Waste as a per cent of real contents deduced by Doyle.
10 inches	65	23	65
14 inches	127	62	51
16 inches	167	90	46
18 inches	211	122	42
20 inches	261	160	39
24 inches	376	250	34
30 inches	588	422	28
36 inches	847	640	25
40 inches	1,046	810	23
50 inches	1,635	1,322	20

[2] Note from page 332, Report 1893, "Determining rotation."

The total amount of wood standing in such a forest at the time of entering upon the work would represent the normal stock—the wood capital which must be maintained in order to insure an equal annual yield. The average difference of the amounts of wood standing in any two compartments would represent the normal annual accretion—the amount of wood which we are entitled to harvest if we desire to secure a continuous revenue in equal annual amounts.

If, for example, on our 100 acres managed with a 100-year rotation we found the average annual accretion per acre to be 50 cubic feet, the normal stock—the wood capital—which must be maintained on the acre would be found by the addition of the contents of all compartments, as $\frac{100 \times 50}{2} \times 100 = 250{,}000$ cubic feet. The total normal yield which we are entitled to harvest would be represented by the oldest 100 year-old compartment, containing, naturally, $50 \times 100 = 5{,}000$ cubic feet, or 2 per cent of the normal stock.

If we were to cut more than this normal yield in any year, we would be trenching on the capital stock and disturb the attempted equalization of income. If we were to cut less, we would unnecessarily accumulate capital in the wood, which would be lying idle and be for the time unremunerative.

The conception of a normal forest, with normal stock, normal accretion, normal distribution of age classes, and normal yield, first taught in 1788, is a most useful one, representing an ideal or standard which, although in practice never attained and hardly fully attempted, serves nevertheless as a guide in calculation and working plans.

In practice the growths of different age may be distributed in compartments of separate areas or they may be distributed in single trees over the entire area or in groups of trees, and thus many variations of the method may occur, but they are all based on the same principle of maintaining a wood capital distributed over a number of age classes in such amounts that the oldest classes always represent what may be cut as the annual or periodic revenue which has accumulated on the entire capital.

Before even an approach to such ideal and systematic condition can be secured in our virgin woods a long time must elapse—the period during which the regulation is gradually perfected, the length of which depends upon the condition of the forest area. If begun with a well stocked virgin forest composed of old and young timber of varying age, the conditions are most favorable, and a systematic management can be instituted in a comparatively short time and with a revenue from the start.

In any case it requires a strong mind and persistent effort on the part of the owner to accumulate the wood capital, to forego, if need be, present revenue for future profits and to keep capital and interest account in the growing crop clearly separate, and to abstain from cutting into the wood capital before it has done its full duty when tempting opportunity arises for liquidating it.

This fact, namely, that a differentiation into fixed capital and interest as represented in the growing timber and the harvest is not readily recognizable—that the choice of when to harvest the growth is not based on natural conditions so much as on the opinion and pecuniary interest of the owner, and in addition that there is a long time during which he could if he chose turn the accumulated fixed capital into cash—may sometimes, to be sure, appear as an advantage from the standpoint of private industry, but from that of national economy it is fraught with danger, as it is apt to lead to uneconomical use of the forest resource whenever the owner finds himself in difficulties or sees a temporary advantage in reducing this capital, which can be restituted only by the expenditure of a long time.

If a farmer sells his cattle, horses, plows, etc., and leaves the ground to fallow, he may suffer loss individually, but the community does not, or at least only to a slight degree; for while, to be sure, the land does not produce, it accumulates in the fallow conditions the elements of fertility, and as a rule is not long allowed to remain unused and can in a season's time be made to produce again.

On the other hand, if a forest growth is removed without reference to the requirements of a regulated management, namely, without leaving a wood capital of useful kinds upon which a new growth can accumulate, not only is the area of wood production reduced, but in the new spontaneous growth of undesirable kinds which, as a rule, come in, an impediment to useful occupation

of the soil is invited, while by the sudden excessive offer of material followed by corresponding decrease of supplies the market and prices are disturbed and the rational management (if existing) of neighboring forest areas unfavorably influenced.

Such disturbances leading to trade depressions, while in the end they are equalized by trade booms, are never desirable, and especially not in an industry which requires such a long time to gain an equilibrium.

To be sure, the growing of wood crops, as in agriculture may be carried on in a small way with a small wood capital, or else in a large way with a large wood capital, but it will be readily seen that since the most useful, most necessary, and most valuable sizes of timber upon which the lumber industry of the country is based requires not less than a century for their production, this industry must finally be carried on by large capital, preferably by corporations, which have in them the elements of perpetuity, and eventually by the Government.

The present consumption, for instance, of the lumber industry in the United States may be set at 40,000,000,000 feet B. M. annually, which corresponds to about 5,000,000,000 cubic feet of log timber in the woods; the normal wood reserve, which under first-class management could be expected to furnish such amounts continuously, would figure up to at least 1,000 billion cubic feet, which would require 400,000,000 acres fully stocked in good condition to be constantly kept in wood.

Figuring the stumpage value somewhat like the present average rates at 2 cents per cubic foot it appears that a capital of at least $20,000,000,000 would have to be tied up in the wood capital which is capable of furnishing continuously the present requirements of our lumber market. In this calculation we assume that our requirements for firewood and other forest products, not lumber and timber, can be satisfied by the inferior material remaining over after the log timber has been taken out, which is not now the case.

The experience of European nations has amply demonstrated that the small forest owner soon tires of the burden of maintaining the wood capital; he reduces it by shortening the rotation more and more, confining himself finally to the production of firewood and inferior sizes, and being unable to acquire or employ the skill necessary to carry on a systematic forestry business, his wood lots deteriorate more and more and play no rôle in the supplies for the lumber market which are furnished by the State forests and the large landed proprietors, who can keep up well-stocked areas of large enough size to pay for the employment of competent managers and skilled labor and the maintenance of a business organization; who can leave the large wood capital intact, which with the long rotation is necessary to produce sizable material, and who are satisfied with the low but steady and safe interest which their capital produces.

H. FOREST INFLUENCES.

[Condensed from Bulletin 7, Forest Influences, pp. 191, 1893, with additional notes.]

One of the arguments upon which a change of policy in regard to our forests, and especially on the part of the National Government, is demanded, refers to the influence which it is claimed forest areas exert upon climate and water flow. It is argued that the wholesale removal and devastation of forests affects climate and water flow unfavorably.

Popular writers on forestry, friends of forestry reform, and the public mind have readily taken hold of this proposition, enlarged upon it, and generalized without sufficient and relevant premises, and before it was possible for science and systematic observations to furnish grounds or sound deductions; hence we have had only presumptions supported by superficial reasoning and occasional experiences. Even scientific writers have discussed the question without proper bases, and have sought to reason out the existence or absence of such an influence upon general premises and such evidence as the history of the world seemed to furnish, or else upon observations which were either of too short duration to allow elimination of other disturbing factors or else were otherwise unreliable.

From the complication of causes which produce climatic conditions it has always been difficult to prove, when changes of these conditions in a given region were observed, that they are permanent and not due merely to the general periodic variations which have been noted in all climates of the earth, or that they are due to a change of forest conditions and to no other causes; hence some climatologists have thought proper to deny such influences entirely. On the other hand there are as trustworthy and careful observers who maintain the existence of such influences; but only of late has the question been removed from the battlefield of opinions, scientific and unscientific, to the field of experiment and scientific research, and from the field of mere speculation to that of exact deduction. But the crop of incontrovertible facts is still scanty, and further cultivation will be necessary to gather a fuller harvest and then to set clear the many complicated questions connected with this inquiry.

Meanwhile a thorough beginning with a view to settle the question by scientific methods and careful systematic measurements and observations has been made in Europe, where the existence of well-established forest administrations, manned with trained observers, has rendered practicable the institution of such work on an extensive scale—the only one which can yield adequate results. Nevertheless, the results of these experiments, cited below, have so far failed to advance materially our positive knowledge regarding the relation of forest growth and meteorological phenomena.

The reason for this failure is to be sought, first, in the complexity of the problem, which renders any experimentation difficult, and, secondly, in the deficiency in appliances and methods of meteorological observations.

Not only is it difficult to analyze or control the various causes that may influence climatic variations from year to year, but we are not yet prepared to determine the uniformity of the local distribution of meteorological phenomena or of the measurements of the same by our instruments.

Hence some of the small, though well-defined differences in rainfall and temperature observed over forest and open country in earlier experiments may be attributed to the nonconformity of the natural local distribution of these phenomena or to lack of uniformity in instruments and methods.

It may be proper to call attention to and accentuate the fact that the question of practical importance is not so much as to the effects upon the general climate, but as to the local modification of climatic conditions which a forest area may produce.

It can not be too strongly impressed upon those who disclaim any influence of forest cover on climate, because the cosmic causes by which this is produced are immeasurably greater, that there are two classes of climate always to be considered separately, namely, the general climate and the local climate. The latter is of most importance to us, and alone can be modified by small causes. We modify it by building a house around us, thus altering the temperature and moisture conditions of the atmosphere so inclosed; but the question is, whether we can alter these conditions on a larger scale by such means as alternating forest areas and fields or by large bodies of forest. We are not so much concerned as to whether the total rainfall over the continent is increased, but whether the distribution of precipitation in time and quantity over and near a forest area is influenced by its existence; whether we or our crops feel its absence or presence in our immediate neighborhood; whether the protection it seems to afford and the changes it seems to produce in the meteorological phenomena are or are not real and of sufficient magnitude to influence our forest policy.

We can understand readily that if any influence exists it must be due, in the first place, to the mechanical obstruction which the forest cover presents to the passage of air currents and to the action of the sun's rays upon the soil—it must result from a difference in insolation, and consequent differences in temperature and evaporation over forest and field. It is also readily understood that the influence can become appreciable only when large enough areas exhibiting such differences are opposed to each other, capable of producing local currents of air which may intercommunicate the characteristics of the one area to the other. The size and character of the forest growth, its density, height, situation, and composition are, therefore, much more important in determining its influence than has been hitherto supposed. It is not trees, but masses of foliage which may be effective. A large sheet covering an extended area from the influence of the sun would produce almost the same differences in meterological conditions that a forest cover is expected to produce.

While, then, we may admit a priori that extent or area and condition of the forest cover are important, we have as yet no data from which to calculate any proper size or proportion, and the attempts to fix a certain percentage of forest cover needed for favorable climatic conditions of a country are devoid of all rational basis.

Leaving the question of forest influences upon climate as still awaiting final solution, we may speak with much more confidence of the effect which forest cover exerts upon the disposal of water supplies. This effect can be much more readily studied and shows itself much more conspicuously. It is perhaps also much more important to human economy, for it is becoming more and more apparent that our agricultural production is dependent not so much upon the amount of rainfall as upon the proper disposal of the waters that fall.

Recognizing this truth, the American Association for the Advancement of Science in 1891 sent the following resolution to the Secretary of Agriculture:

> The American Association for the Advancement of Science respectfully submits for the consideration of the Secretary of Agriculture that the future of successful and more productive agriculture depends very largely upon a rational water management, meaning thereby not only the use of water for irrigation in the arid and subarid regions, but the rational distribution and use in the humid regions of available water supplies by means of horizontal ditches and irrigation systems, combined with proper mechanical preparation of the soil, and with drainage systems, with the object of fully utilizing the water for plant production and providing for the safe and harmless removal of the surplus.
>
> The present policy of forest production and of allowing our waters to run to waste not only entails the loss of their beneficial influence upon plant production, but permits them to injure crops, to wash the fertile mold from the soil, and even to erase and carry away the soil itself.
>
> It is upon these considerations that the association respectfully suggests to the honorable Secretary the desirability of utilizing the Weather Bureau, the various agricultural experiment stations, and other forces, in forming a systematic service of water statistics, and in making a careful survey of the condition of water supplies, which may serve as a basis for the application of rational principles of water management.

How poorly we understand the use of these supplies is evidenced yearly by destructive freshets and floods, with the accompanying washing of soil, followed by droughts, low water, and deterioration of agricultural lands.

It may be thought heterodox, but it is nevertheless true, that the manner in which most of the water of the atmosphere becomes available for human use (namely, in the form of rain) is by no

means the most satisfactory, not only on account of its irregularity in time and quantity, but also on account of its detrimental mechanical action in falling; for in its fall it compacts the ground, impeding percolation. A large amount of what would be carried off by underground drainage is thus changed into surface drainage waters. At the same time, by this compacting of the soil, capillary action is increased and evaporation thereby accelerated. These surface waters also loosen rocks and soil, carrying these in their descent into the river courses and valleys, thus increasing dangers of high floods and destroying favorable cultural conditions.

Here it is that water management and, in connection with it or as a part of it, forest management should be studied; for without forest management no rational water management is possible. The forest floor reduces or prevents the injurious mechanical action of the rain and acts as a regulator of water flow. Hitherto water management in rainy districts has mainly concerned itself with getting rid of the water as fast as possible, instead of making it do service during its temporary availability by means of proper soil management, horizontal ditches and reservoirs—drainage and irrigation systems combined. It seems to have been entirely overlooked that irrigation, which has been considered only for arid and subarid regions, is to be applied for plant production in well-watered regions with equal benefit and profit, if combined with proper drainage systems and forest management.

The experimental demonstration of this influence of forests and water flow is also still in doubt, and the problem is as difficult and complex as that regarding the influence on temperature and rainfall. Nevertheless, sufficient experience exists to sustain the general philosophy, to which a close student of nature is forced, long before he can demonstrate the qualitative and quantitative character of an important influence of forests on water conditions.

Summary of Conclusions.

For those who wish to know only what the present state of the question of forest influences is, we have summarized what conclusions may be drawn from the facts presented in Bulletin 7, referring them to that report for the basis of these conclusions and the discussion in extenso. For easy reference the pages of the bulletin containing the data upon which each conclusion is reached are given in parentheses at the end of each paragraph, and the diagrams which show in graphic manner the result of the observations upon which the conclusions are mainly based are reproduced. There are also added to this summary some references to later developments in this subject.

GENERAL CONSIDERATIONS.

(1) We must keep separate two main questions, namely, What is the difference of conditions within and without the forest? and How far is the difference of conditions within the forest communicated to the outside, i. e., how far does the forest influence the conditions outside? (Pp. 23–40, Bul. 7.)

(2) The general climatic conditions in which the forest is situated as well as its situation with reference to elevation and exposure, furthermore its composition, whether evergreen or deciduous, its density, its height and extent, the character of the forest floor, and other features which determine its quality, must all combine in producing variety, at least quantitatively, both as to difference of conditions within and without the forest and as to possible exchange of the same, and hence the question of forest influences can be properly discussed only with reference to these other conditions. We must refrain from generalizing too readily from one set of conditions to another set of conditions. (Pp. 40–121, Bul. 7.)

(3) In the matter of forest influence upon water flow, besides the above mentioned, other conditions, the topography and geology or stratification of soil, must also be taken into account and generalizations without regard to these must be avoided. (Pp. 123–157, Bul. 7.)

(4) No influence upon the general climate which depends upon cosmic causes can in reason be expected from a forest cover. Only local modifications of climatic conditions may be anticipated; but these modifications, if they exist, are of great practical value, for upon them rest success or failure in agricultural pursuits and comfort or discomfort of life within the given cosmic climate. The same condition must be insisted upon with reference to forest influences upon water flow, which can exist only as local modifications of general water conditions, which are due in the first place to climatic, geologic, and topographic conditions. (Pp. 157–170, Bul. 7.)

DIFFERENCE OF METEOROLOGICAL CONDITIONS WITHIN AND WITHOUT THE FOREST.

(1) *Soil temperatures.*—The general influence of the forest on soil temperatures is a cooling one, due to the shade and to the longer retention of moisture in the forest floor as well as in the forest air, which must be evaporated before the ground can be warmed. As a consequence, the extremes of high and low temperature within the forest soil occur much later than in the open, and both extremes are reduced, but the extreme summer temperatures much more than the winter temperatures. (Pp. 40–46, Bul. 7.)

The difference between evergreen and deciduous forests, which almost vanishes in the winter time, is in favor of the deciduous as a cooling element in summer and autumn, while during spring the soil is cooler under evergreens. The effect increases naturally with the age and height of the trees. (Pp. 46–50, Bul. 7.)

(2) *Air temperatures under the crowns.*—The annual range of air temperature is smaller in the forest than in the open; the effect upon the minimum temperature (i. e., the effect in winter) is less than on the maximum temperature (i. e., the effect in summer.) The combined effect is a cooling one. The range of temperature is more affected than the average absolute temperature, or, in other words, the moderating influence is greater than the cooling effect. (Pp. 51–53, Bul. 7.)

The monthly minima for middle latitudes are uniformly reduced during the year, and the monthly maxima are much more reduced during the summer than during the winter. On the average the forest is cooler than the open country in summer, but about the same in winter, with a slight warming effect in spring. (Pp. 53–58, Bul. 7.)

The difference between the mean monthly air temperatures in the woods and in the open varies with the kind of forest much more than is the case for soil temperatures. The evergreen forest shows a symmetrical increase and decrease throughout the year. The deciduous forest shows a variable influence which diminishes from the midwinter to springtime, but increases rapidly as the leaves appear and grow, becoming a maximum in June and July and then diminishing rapidly until November. The annual average effect is about the same both for evergreens and deciduous forests. (Pp. 58–60, Bul. 7.)

Forests situated at a considerable elevation above the sea have sensibly the same influence on the reduction of the mean temperature as do forests that are at a low level. (P. 60, Bul. 7.)

Young forests affect the air temperature very differently from mature forests; in the former the minimum temperatures are always reduced, but the maxima are exaggerated. The observations on which this conclusion is based ought, perhaps, to be considered as pertaining rather to the case of temperatures in the tree tops. (P. 60, Bul. 7.)

(3) *Air temperatures within the crowns.*—The mean temperature of the air in the tree tops, after correcting for elevation above ground, is rather higher than over open fields. The effect of tree tops does not appreciably depend upon the height of the station above ground. The effect upon the minima is generally greater than on the maxima, the total effect being a warming one. A tree-top station is in general intermediate, as to temperature, between a station near the ground in the forest and one in the open field. (Pp. 61–66, Bul. 7.)

Evergreen forests show less difference between the temperature in the crown and below, and altogether more uniformity in temperature changes throughout the year, than deciduous growth. (P. 67, Bul. 7.)

The vertical gradient for temperature within the forest on the average of all stations and all kinds of forest trees is large, varying from 0.61° F. per 100 feet in April to 2.50° F. in July. (P. 68, Bul. 7.)

A reversal of the vertical gradient, namely, a higher temperature above than below, occurs in the wood, especially in the summer time. It also occurs in the open air regularly at night, and may be three or four times as large as that just mentioned. In general, the action of the forest tends to produce a vertical distribution of temperature like that over snow or level fields on clear nights. (P. 69, Bul. 7.)

(4) *Air temperature above the crowns.*—The temperature, at considerable heights above the forest, appears to be slightly affected by the forest, and more so with evergreens than with deciduous growth. The vertical gradients of temperature within 30 feet above the tops of the trees are all reversed throughout the leafy season; the gradients are also greater above the tree crown than below, at least during the clear sky and calm air. The wind affects the temperature

under and within the crowns, but makes little difference above them. The surface of the forest crown appears meteorologically much like the surface of the meadow or cornfield. It is as if the soil surface has been raised to the height of the trees. (Pp. 69–72, Bul. 7.)

(5) *Air temperature in general.*—From the preceding generalizations it appears that the forest affects the temperature just as any collection of inorganic obstacles to sunshine and wind; but as an organic being the forest may be also an independent source of heat. Careful observations of the temperature within the trunk of the tree and of the leaves of the tree show that the tree temperature is affected somewhat by the fact that the water rising brings up the temperature of the roots, while the food material from the leaves brings their temperature down, and the tree temperature, considered as the result of the complex adjustment, is not appreciably affected by any heat that may be evolved by the chemical processes on which its growth depends. It is not yet clear as to whether the chemical changes that take place at the surface of the leaves should give out any heat; it is more likely that heat is absorbed, namely, rendered latent, especially in the formation of the seed; the process of germination usually evolves this latent heat; the immense quantity of water transpired and evaporated by the forests tends to keep the leaves at the same temperature as that of the surface of water or moist soil. (Pp. 73–95, Bul. 7.)

(6) *Humidity of air.*—The annual evaporation within the forests is about one-half of that in the open field; not only is the evaporation within a forest greatest in May and June, but the difference between this and the evaporation in the open field is also then a maximum, which is the saving due to the presence of the woods. The average annual evaporation within the woods is about 44 per cent of that in the field. Fully half of the field evaporation is saved by the presence of the forest. (P. 96, Bul. 7.)

The quantity of moisture thrown into the air by transpiration from the leaves in the forest is sometimes three times that from a horizontal water surface of the same extent, and at other times it is less than that of the water. The transpiration from leaves in full sunshine is decidedly greater than from leaves in the diffused daylight or darkness. The absolute amount of annual transpiration, as observed in forests of mature oaks and beeches in central Europe, is about one-quarter of the total annual precipitation. (Pp. 77–80, Bul. 7.)

The percentage of rainfall, evaporated at the surface of the ground, is about 40 per cent for the whole year in the open field and about 12 per cent for the forest, and is greater under deciduous than under evergreen forests. (P. 98, Bul. 7.)

The evaporation from a saturated bare soil in the forest is about the same as that from a water surface in the forest, other conditions being the same. (P. 99, Bul. 7.)

The presence of forest litter like that lying naturally in undisturbed forests hinders the evaporation from the soil to a remarkable extent, since it saves seven-eighths of what would otherwise be lost. (P. 100, Bul. 7.)

The total quantity of moisture returned into the atmosphere from a forest by transpiration and evaporation from the trees and the soil is about 75 per cent of the precipitation. For other forms of vegetation it is about the same or sometimes larger, varying between 70 per cent and 90 per cent; in this respect the forest is surpassed by the cereals and grasses, while, on the other hand, the evaporation from a bare soil is scarcely 30 per cent of the precipitation. (P. 101, Bul. 7.)

The absolute humidity within a forest exceeds that of the glades and the plains by a small quantity. The relative humidity in the forest is also larger than in the glades or plains by 2 per cent to 4 per cent. Forests of evergreens have from two to four times the influence in increasing relative humidity than do forests of deciduous trees. (Pp. 102–105, Bul. 7.)

The gauges in European forest stations catch from 75 to 85 per cent when placed under the trees, the balance representing that which passes through the foliage and drips to the ground or runs down along the trunks of trees, or else is intercepted and evaporated. The percentage withheld by the trees, and which either evaporates from their surface or trickles along the trunk to the ground, is somewhat greater in the leafy season, though the difference is not great. Deciduous and evergreen trees show but slight differences in this respect. More rain is usually caught by gauges at a given height above the forest crown than at the same height in open fields, but it still remains doubtful whether the rainfall itself is really larger over the forests, since the recorded catch of the rain gauge still requires a correction for the influence of the force of the wind at the gauge. (Pp. 106–110, Bul. 7).

In such cases, where over a large area deforestation and reforestation have seemingly gone

hand in hand with decrease and increase of rainfall, the possible secular change in rainfall must also be considered. Yet the experience of increased rainfall over the station at Lintzel, with increase of forest area, points strongly toward a possible interdependence under given conditions. (Pp. 111–118, Bul. 7.)

By condensing dew, hoar frost, and ice on their branches, trees add thereby a little to the precipitation which reaches the ground, and by preventing the rapid melting of snow more water remains available under forest cover. (P. 121, Bul. 7.)

The question as to the march of destructive hailstorms with reference to forest areas, which seems settled for some regions in France, remains in doubt for other, especially mountain, regions. (Pp. 121–129, Bul. 7.)

From these statements we would expect as a consequence of deforestation an effect on the climate of the deforested area in three directions, namely: (*a*) extremes of temperature of air as well as soil are aggravated; (*b*) the average humidity of the air is lessened; and possibly (*c*) the distribution of precipitation throughout the year, if not its quantity, is changed.

INFLUENCE OF FORESTS UPON THE CLIMATE OF THE SURROUNDING COUNTRY.

(1) An influence of the forest upon the climate of its surroundings can only take place by means of diffusion of the vapor which is transpired and evaporated by the crowns and by means of air currents passing through and above the forests being modified in temperature and moisture conditions; the mechanical effect upon such air currents by which they are retarded in their progress may also be effective in changing their climatic value.

(2) Local air currents are set up by the difference in temperature of the air within and without the forest, analogously to those of a lake or pond, cooler currents coming from the forest during the day in the lower strata and warmer currents during the night in the upper strata. The latter currents, being warmer and moister, can be of influence on the temperature and moisture conditions of a neighboring field by moderating temperature extremes and increasing the humidity of the air.

This local circulation is the one most important difference between forest and other vegetation. How far away from the forest this circulation becomes sensible is not ascertained. In winter time, when the temperature differences become small, no such circulation is noticeable. (P. 120, Bul. 7.)

(3) The general air currents in their lower portions are cut off entirely by the forest, which acts as a wind break. This influence can of course be experienced only on the leeward side. How far this protection reaches it is difficult to estimate, but it certainly reaches farther than that of a mere wind break, since by the friction of the air moving over the crowns a retardation must be experienced that would be noticeable for a considerable distance beyond the mere wind-break effect. Deforestation on a large scale would permit uninterrupted sweep of the winds, a change more detrimental where the configuration of the ground does not fulfill a similar function—in large plains more than in hilly and mountainous regions, and at the seashore more than in the interior. (Pp. 118–120, 133, Bul. 7.)

The upper air strata can be modified only by the conditions existing near and above the crowns. At the same time they must carry away the cooler and moister air there and create an upward movement of the forest air, and thereby in part the conditions of this become also active in modifying air currents. The greater humidity immediately above the crowns is imparted to the air currents, if warm and dry, and becomes visible at night in the form of mists resting above and near forest areas. These strata protect the open at least against insolation and loss of water by evaporation, and have also a greater tendency to condensation as dew or light rain if conditions for such condensation exist. This influence can be felt only to the leeward in summer time, and with dry, warm winds, while the cooling winter effect upon comparatively warmer moist winds is not noticeable. Theoretical considerations lead to the conclusion that in mountain regions only the forest on the leeward slope can possibly add moisture to a wind coming over the mountain, but this does not necessarily increase the precipitation on the field beyond. Altogether, the theoretical considerations are as yet neither proved nor disproved by actual observations, and as to rainfall the question of influence on the neighborhood is still less settled than that of precipitation upon forest areas themselves. Wherever moisture-laden winds pass over extensive forest areas the cooler and moister condition of the atmosphere may at least not reduce the possibility

of condensation, which a heated plain would do; but observations so far give no conclusive evidence that neighboring fields receive more rain than they otherwise would. (Pp. 76, 83, 89, 103, Bul. 7.)

(4) With regard to comparative temperatures in forest stations and open stations that are situated not far apart from each other, it would appear that the forest exerts a cooling influence, but that more detailed conclusions are hindered by the consideration that the ordinary meteorological station itself is somewhat affected by neighboring trees.

The study of the stations in Asiatic and European Russia seems to show that in the western part of the Old World the presence of large forests has a very sensible influence on the temperature. Similar studies for stations in the United States seem to show that our thin forests have a slight effect in December, but a more decided one in June. It appears also that our wooded regions are warmer than the open plains, but there is no positive evidence that this difference of temperature is dependent upon the quantity or distribution of forests or that changes in temperature have occurred from this cause. (Pp. 94, 95, Bul. 7.)

(5) When a forest incloses a small area of land, forming a glade, its inclosed position brings about special phenomena of reflection of heat, local winds, and a large amount of shade. For such situations it is found that the mean range of temperature is larger in the glade than in the open; the glade climate is more rigorous than the climate of open plains; the glade is cooler and its diurnal range larger during the spring, summer, and autumn. (Pp. 84–88, Bul. 7.)

Favorable influences upon moisture conditions of the air are most noticeable in localities where much water is stored in underground with overlying strata which are apt to dry when our summer drought prevails. Here the forest growth is able to draw water from greater depths and by transpiration return it to the atmosphere, thereby reducing the dryness and possibly inducing precipitation. In most climates this action would be less effective or of no use. Hence in regions with oceanic climate, with moist sea winds, like England and the west coasts of Europe or of the northern United States, deforestation from a climatic point of view may make no appreciable difference, such as it would make in continental climates like the interior of our country, the Rocky Mountains, and southern California.

Whether large or small areas of forest and open fields alternating or what percentage of forest is most favorable can not as yet be discussed, since we are not clearly informed even as to the manner and the amount of influence which forest cover exercises. In general, we may expect that an alternation of large forested and unforested areas in regions which on account of their geographic situation have a dry and rigorous climate is more beneficial than large uninterrupted forest areas, which would fail to set up that local circulation which is brought about by differences in temperature and permits an exchange of the forest climate to the neighboring field.

More recent experiments tend to modify somewhat the conclusions arrived at heretofore, and indicate, as has been suggested, that the differences in temperature and humidity of woods and of open land that have been recorded are largely to be attributed to variability of instruments and of readings, and to nonconformity of conditions.

Even the well-planned Austrian experiments have produced neither striking nor consistent results. In 1893, Dr. Lorentz Liburnau concluded that forests did not cool the air of the surrounding country, and that temperature extremes were even heightened in the immediate vicinity of the woods. Concerning humidity, it was found that while with one set of stations this appeared increased by an uncertain trifle through the proximity of the forest, in another set no influence was observed, and in one case the air current from the woods was positively drier at noon time than that of the open country, and even though Lorentz Liburnau is still hopeful in the matter he felt compelled to admit that a "distance effect" of forest influence was so far not demonstrated.

Schubert, in 1895 and again in 1897, published results of extensive temperature measurements which point to an entire absence of influence in this respect, the air of the forest being in no case sufficiently cooler to warrant a decision. His experiments gave a difference of only 5° F. in favor of the pine woods. This author came to practically the same conclusion regarding the humidity of the forest and the open country.

Müttrich, in 1896, comparing different modes of placing the thermometers found that these thermometers side by side varied by as much as 1.2° F.

In a recent investigation of the methods employed in investigations of this character Hoppe

arrived at the following results: A number of the most approved instruments placed side by side and read at the same time of day gave readings differing by as high as 1.6° F., and usually by as much as 0.7° F., thus indicating clearly that such differences of temperature as had hitherto been considered real or valid differences were possibly nothing more than inaccuracies or insufficiencies of observation or due to nonuniformity of conditions. Nevertheless, having thus ascertained the difficulties and errors of instruments, Hoppe proceeded to investigate the influence of soil covers and found that even over the sod of a poor meadow the temperature is lower and the humidity greater than over a piece of rocky bare land, temperature and humidity being measured by the same instruments in both cases. He finds that this is still more constant and pronounced when forest and bare land are compared. The differences were small, however, the average of his results for sixty-six days being a difference in temperature of 3.2° F., and in relative humidity of 7 per cent. His results would seem to indicate a great uniformity of difference, and that the differences in temperature and humidity are nearly as great at night as during the day. A point of great interest is also brought out prominently by these experiments, namely, the need of a large number of observations. Thus, Hoppe found that the same instrument (an Assmann aspiration psychrometer) varied from minute to minute often with the slightest changes in cloudiness, so that during noonday and in one minute the relative humidity fell from 47.4 per cent to 41.2 per cent, and the temperature rose from 73.5 to 75° F., and within five minutes the humidity rose from 43.8 to 50.9, fell to 48.8 and rose again to 52.2.

WIND-BREAK EFFECTS.

Prof. F. W. King, of the University of Wisconsin, has made an investigation into the protection afforded by wind breaks, and records his observations in Bulletin 42 of that institution. The following extracts show the general character of his observations:

Lying to the eastward of a field of clover, seeded last year, is a piece of oats seeded to clover, and here the catch is very much better close to the grass, and is evidently so as far out in the field as 2 rods.

A north-and-south road, fenced with wire and 2 rods wide, has scattering trees from 10 to 18 feet high, together with a scanty growth of hazel on both sides. To the east of this is a field of oats badly damaged by the winds at a distance from the shelter, but a strip 2 rods wide adjoining that seems wholly to have escaped injury.

A level field seeded to clover and timothy last year is bounded on the north by a road and a strip of woods. Here the clover has a much thicker stand and ranker growth in a belt alongside than it has to the southward.

Coming next to a field of oats some 60 rods from east to west and 30 rods north to south, lying east of a piece of woods, we find its whole eastern two-thirds so completely ruined that it is scarcely more than a naked field, while the western third is fresh and green.

Another piece of oats seeded to clover, and lying on the south side of a wooded pasture, has a length of 80 rods from east to west, but a width of only 15 rods. This field is fresh and green throughout its whole extent and has a good catch of clover, but the patch is best and thickest in the strip 3 rods wide along the wooded pasture.

Influence of woods on the rate of evaporation to the leeward.—To study the rate evaporation at different distances from groves, six evaporimeters were used made after the plan of the Piche evaporimeter, but with the evaporating surface much larger, while the graduated tubes were the same size, the object being to make the instruments more sensitive.

Sheets of chemical filter paper were used as the evaporating surfaces, all from the same packages and having a diameter of 5.9 inches; this gives an area, after deducting that covered by the graduated tube, of 27.06 square inches.

The first experiment was made to the northwest of Plainfield on a piece of ground planted to corn, lying to the south of a grove of black oaks having a mean height not far from 12 to 15 feet. At the time there was a gentle breeze from a little west of north. The instruments were all suspended at a height of 1 foot above the surface of the ground and unsheltered in any way from the wind or sun, and in the first trial they were placed at intervals of 20 feet along a line at right angles to the south margin of the woods. The amount of evaporation at the six stations between 11.30 a. m. and 12.30 p. m., is given in the following tables:

	Cubic centimeters.
At Station A, 20 feet from woods, the evaporation was	11.5
At Station B, 40 feet from woods, the evaporation was	11.6
At Station C, 60 feet from woods, the evaporation was	11.9
Sum	35.0
At Station D, 280 feet from woods, the evaporation was	15.5
At Station E, 300 feet from woods, the evaporation was	14.2
At Station F, 320 feet from woods, the evaporation was	14.7
Sum	43.4

These are the amounts of evaporation in one hour, and they show that the difference between 20 to 60 feet from the woods and that between 280 to 320 feet was 43.4 — 35.0 = 8.4 c. c., and this is 24 per cent greater evaporation at the three outer stations than at the three inner ones.

On May 31 another trial was made in the town of Almond, to the south of an oak grove 80 rods square, in a field sowed to oats and wheat mixed. Here the first instrument was placed 20 feet from the margin of the grove, the second 100 feet distant, the third 200 feet, etc. The first two instruments stood upon ground seeded last year to clover and timothy, but only timothy was growing where the second instrument stood. The grain upon the field had a fair stand where the observations were made, and was about 4 inches high. There was at the time a fair wind from nearly due north and the day was clear. As in the former trials the evaporometers were suspended at a height of 1 foot above the ground and were unsheltered in any way. The following table expresses the results obtained:

	Cubic centimeters.
At Station A, 20 feet from woods, the evaporation was	11.1
At Station B, 100 feet from woods, the evaporation was	14.3
At Station C, 200 feet from woods, the evaporation was	15.7
At Station D, 300 feet from woods, the evaporation was	18.5
At Station E, 400 feet from woods, the evaporation was	18.5
At Station F, 500 feet from woods, the evaporation was	18.3

From this table it will be seen there is an increasing amount of evaporation until 300 feet from the woods is reached, and that beyond and including this the rate is practically the same, but at 300 feet the evaporation is 17.7 per cent greater than at 200 feet and 66.6 per cent greater than at 20 feet from the woods.

Influence of a hedgerow on the rate of evaporation to the leeward.—On May 30 three of the instruments were set up to the south of a very scanty hedgerow, consisting of a strip of blue grass 16 feet wide in which there are scattering black and burr oaks from 6 to 8 feet in height, with a few attaining a height of 12 feet. This hedge has very many open gaps in it, and the first instrument is set up behind a clump of six trees, spanning a length of 40 feet, there being a gap of nearly the same width on both sides of it. To the north of this, in the direction from which the wind was blowing, there is a broad naked field being planted to potatoes, which has a width of about 80 rods, while the instruments hung over a field of oats in which the grain was about 4 inches high. After the instruments were set up it became cloudy and sprinkled a very little at times, the wind being from a little east of north, rather strong and chilly. Here again the instruments hung one foot above the surface, and the results obtained are given below:

	Cubic centimeters.
At Station A, 20 feet from hedge, the evaporation was	10.3
At Station B, 150 feet from hedge, the evaporation was	12.5
At Station C, 300 feet from hedge, the evaporation was	13.4

Here it will be seen the evaporation at 300 feet from the hedgerow was 3.1 c. c., or 30.1 per cent greater than at 20 feet distant, and at 150 feet the difference was 0.9 c. c., or 7.2 per cent less than 300 feet. It is evident, therefore, that even such a hedgerow does exert an influence upon the rate of evaporation which is readily measured.

INFLUENCE OF FORESTS UPON WATER AND SOIL CONDITIONS.

(1) In consequence of deforestation, evaporation from the soil is augmented and accelerated, resulting in unfavorable conditions of soil humidity and affecting unfavorably the size and continuity of springs. The influcnee of forest cover upon the flow of springs is due to this reduced evaporation as well as to the fact that by the protecting forest cover the soil is kept granular and allows more water to penetrate and percolate than would otherwise. In this connection, however, it is the condition of the forest floor that is of greatest importance. Where the litter and humus mold is burned up, as in many if not most of our mountain forests, this favorable influence is largely destroyed, although the trees are still standing. (Pp. 130–137, Bul. 7.)

(2) Snow is held longer in the forest and its melting is retarded, giving longer time for filtration into the ground, which also being frozen to less depth is more apt to be open for subterranean drainage. Altogether forest conditions favor in general larger subterranean and less surface drainage, yet the moss or litter of the forest floor retains a large part of the precipitation and prevents its filtration to the soil, and thus may diminish the supply to springs. This is especially possible with small precipitations. Of copious rains and large amounts of snow water, quantities, greater or less, penetrate the soil, and according to its nature into lower strata and to springs. This drainage is facilitated not only by the numerous channels furnished by dead and living roots, but also by the influence of the forest cover in preserving the loose and porous structure of the soil.

Although the quantity of water offered for drainage on naked soil is larger, and although a large quantity is utilized by the trees in the process of growth, yet the influence of the soil cover in retarding evaporation is liable to offset this loss, as the soil cover is not itself dried out.

The forest, then, even if under unfavorable topographical and soil conditions (steep slopes and impermeable soils) it may not permit larger quantities of water to drain off underground and in springs, can yet influence their constancy and equable flow by preventing loss from evaporation. (Pp. 137–140, Bul. 7.)

(3) The surface drainage is retarded by the uneven forest floor more than by any other kind of soil cover. Small precipitations are apt to be prevented from running off superficially through absorption by the forest floor. In case of heavy rainfalls this mechanical retardation in connection with greater subterranean drainage may reduce the danger from freshets by preventing the rapid collection into runs. Yet in regions with steep declivities and impermeable soil such rains may be shed superficially and produce freshets in spite of the forest floor, and an effect upon water conditions can exist only from the following consideration. (Pp. 140–159, Bul. 7.)

(4) The well-kept forest floor, better than even the close sod of a meadow, prevents erosion and abrasion of the soil and the washing of soil and detritus into brooks and rivers.

This erosion is especially detrimental to agricultural interests as well as water flow in regions with this surface and impenetrable subsoils, and where rains are apt to be explosive in their occurrence, as in our western and southern country. The best soil of the farms is often washed into the rivers, and the water stages of the latter by the accumulations of this soil are influenced unfavorably. (Pp. 159–162, Bul. 7.)

(5) Water stages in rivers and streams which move outside the mountain valleys are dependent upon such a complication of climatic, topographic, geological, and geographical conditions at the head waters of their affluents that they withdraw themselves from a direct correlation to surface conditions alone. Yet it stands to reason that the conditions at the head waters of each affluent must ultimately be reflected in the flow of the main river. The temporary retention of large amounts of water and eventual change into subterranean drainage which the well-kept forest floor produces, the consequent lengthening in the time of flow, and especially the prevention of accumulation and carrying of soil and detritus which are deposited in the river and change its bed, would at least tend to alleviate the dangers from abnormal floods and reduce the number and height of regular floods. (Pp. 162–170, Bul. 7.)

NOTE.—Concerning the moisture of the soil the results of the most recent experiments differ. Ramann, in 1895, published a series of results which indicated that the soil of the forest may be even drier than that of the neighboring open land. This view he finds strengthened by experiments made in small clearings within the forest, where he finds the soil of the sunny side of the clearing and that of the old forest itself decidedly drier than the soil of the shaded part of the clearing, though he also finds the soil under a young bush cover more moist than that under old timber.

Whether a forest cover aids in the accumulation of ground water by improving the permeability of the soil was made the object of an experiment by Wollny in a series of inconclusive small pot experiments which led this investigator to the questionable result that bare land was more conductive to percolation than ground covered either by grass or trees. This would surely be true only if the bare ground, as in the experiments, is kept in an artificial, not natural condition.

Attempts to deduce the influence of forest on water flow from wholesale measurements and observations have been made in this country by Vermeule, of New Jersey (see Proceedings American Forestry Association, Vol. XI, pp. 130–137, and report of N. J. Geological Survey, 1894), and Rafter, of New York (Proceedings of American Forestry Association, Vol. 12, pp. 139–165, and report of State engineer and surveyor of New York, 1896), the former claiming that no appreciable influence existed, the latter calculating the influence of the forest to be equal in value to 5 or 6 inches of rainfall, this amount of moisture being saved by its presence.

Among recent papers which possess the highest value in describing the movements of water in the ground, and thus throw light on a most important phase of the whole subject, Bulletin 32 of the Experiment Station, Fort Collins, Colo., by Prof. L. G. Carpenter, is noteworthy. Professor Carpenter shows that it is possible by mechanical means (ditches in this case) to prevent the rapid run off in high-water time and thus produce a steadier flow of a stream and also raise the level of the ground water, as well as saturate large areas of otherwise arid land. In other words, he shows that in Colorado the work of irrigation has resulted in a rise in the level of the ground water, changing deep wells into shallow ones; that it has taken water out of the Platte and Cache la Poudre rivers and saturated thousands of acres of formerly arid land, the seepage of which has changed dry branches into steady rivulets and supplies already a steady inflow into the rivers, from which the water is taken above the fields. This inflow tends to make these rivers steady and uniform sources of water supply and makes irrigation possible at points below where in former times such irrigation would have been out of the question.

SANITARY INFLUENCE.

(1) The claimed influence of greater purity of the air due to greater oxygen and ozone production does not seem to be significant. (P. 171, Bul. 7.)

(2) The protection against sun and wind and consequent absence of extreme conditions may be considered favorable. (P. 171, Bul. 7.)

(3) The soil conditions of the forest are unfavorable to the production and existence of pathogenic microbes, especially those of the cholera and yellow fever, and the comparative absence of wind and dust, in which such microbes are carried into the air, may be considered as the principal claim for the hygienic significance of the forest. (P. 172, Bul. 7.)

We may summarize that the position of the forest as a climatic factor is still uncertain, at least as to its practical and quantitative importance, but that its relation to water and soil conditions is well established. As a climatic factor, it would appear that the forest of the plain is of more importance than that of the mountains, where the more potent influence of elevation obscures and reduces in significance the influence of their cover; as a regulator of water conditions, the forest of the mountains is the important factor; and since this influence makes itself felt far distant from the location of the forest, the claim for attention of Government activity and for statesmanlike policy with reference to this factor of national welfare may be considered as well founded. Every civilized government must in time own or control the forest cover of the mountains in order to secure desirable water conditions.

In conclusion, I may urge that systematic observations bearing on the subject of forest influences should be instituted in this country by a Government agency, perhaps under the authority of the Weather Bureau and with the cooperation of the agricultural experiment stations. No other country is so well adapted for the study of this question as the United States, offering all the varying climatic conditions of a whole continent under one government, with changes in forest conditions constantly progressing.

GRAPHIC ILLUSTRATIONS.

The following diagrams, reproduced from Bulletin 7, represent more in detail, yet in a succinct manner, the results of the long-extended series of observations by the Prussian forest-meteorological stations. These stations were double stations; i. e., one set of instruments was placed in the forest and a corresponding set at some distance from the forest in open fields. The stations represent varying conditions in geographical and topographical location and in character of forest growth. At Lintzel there was only one station, originally in an extensive open heath, which was gradually planted to forest, allowing an observation of changes due to these changed conditions.

The conditions at the various stations were as follows:

German stations for forest meteorology.

Station.	Latitude.	Longitude east of Ferro.	Elevation.	Kind of trees and age at founding of station.	Distance to margin of forest.		Beginning of observations.
					Forest station.	Field station.	
	° ″	° ″	*Feet.*		*Feet.*	*Feet.*	
Fritzen	54 50	38 13	128	45-year spruce	262	459	1873, x, i.
Kurwien	53 34	39 9	423	80–140-year pines	679	433	1873, xii, i.
Carlsberg	50 28	34 0	2,484	45-year spruce	591	869	1874, xi, i.
Eberswalde	52 50	31 29	79	45-year pines	410	591	1875, xii, i.
Schmiedefeld	50 36	28 28	2,349	60–70-year spruce	984	492	1881, x, i.
Friedrichsrode	51 52	28 14	1,296	65–85-year beeches	367	1,138	1874, x, i.
Sonnenberg	51 45	28 10	2,549	45-year spruce	328	650	1877, vi, i.
Marienthal	52 16	28 38	420	60-year beeches	984	656	1878, v, i.
Lintzel	52 59	27 55	325	....	....	....	1881, iii, i.
Hadersleben	55 16	27 9	125	70–80-year beeches	410	394	1875, x, i.
Schoo	53 36	25 14	10	20-year pines	656	1,640	1876, x, i.
Lahnhof	50 53	25 54	1,998	70-year beeches	2,461	640	1877, vi, i.
Hollerath	50 27	24 3	2,024	45-year spruces	361	328	1874, x, i.
St. Johann	48 29	26 59	2,493	50-year spruces	1,640	656	
Hagenau	48 50	25 28	499	55–65-year pines	4,167	2,192	1875, v, i.
Neumath	48 59	24 57	1,158	45-year beeches	820	820	1875, v, i.
Melkerei	48 25	24 57	3,064	60–80-year beeches	3,937	5,249	1875, v, i.

The compilation of the records at these stations into the ingenious graphic form here presented was made by Mr. Mark W. Harrington, formerly Chief of the United States Weather Bureau; they explain themselves without the need of additional text to any one who will learn to read them with the aid of the following explanation and show at a glance the difference of meteorological conditions prevailing in the forest and in the open.

NOTE ON THE CONSTRUCTION AND READING OF THE DIAGRAMS.

The horizontal lines (ordinates) above or below the zero line represent values or amounts, degrees of temperature, inches of precipitation or evaporation, percentages, etc. The vertical lines (abscissæ) represent time, dividing the field into twelve seasonal divisions corresponding to the twelve months of the year, the outer lines both standing for the month of December or commencement of winter. The curve lines are constructed by noting on each monthly line the values found for the month, and then connecting these points by either straight or rounded-off lines.

Unless otherwise noted, the values so plotted are the differences between the readings under two sets of conditions, namely, in most cases the values which were found for the stations in the woods (W) diminished by the values found for the stations in the open field (O), or $W-O$.

The value of this difference is positive, if the curve runs above the zero line—that is to say, the records for the woods (W) showed higher values than for the open field (O); it is negative, i. e., the record for the woods was lower, if the curve line runs below the zero line. The greater, therefore, the vertical distance of any point in the curve from zero line, the greater is the influence of the woods. In temperature readings, for instance, the curve above the zero line would denote that the woods were warmer; below the zero line, that the woods were cooler than the open field by as many degrees as the curve runs above or below the zero line, the latter representing that state of conditions when W=O, i. e., when there is no difference in the readings for the two sets of conditions.

Where values for each set of conditions are plotted separately, the area included within the two curve lines (hatched) exhibits the difference between the woods and open field.

To exhibit more readily the amount of influence of the forest, the areas included by the zero line and the curve for mean values is also hatched in most cases.

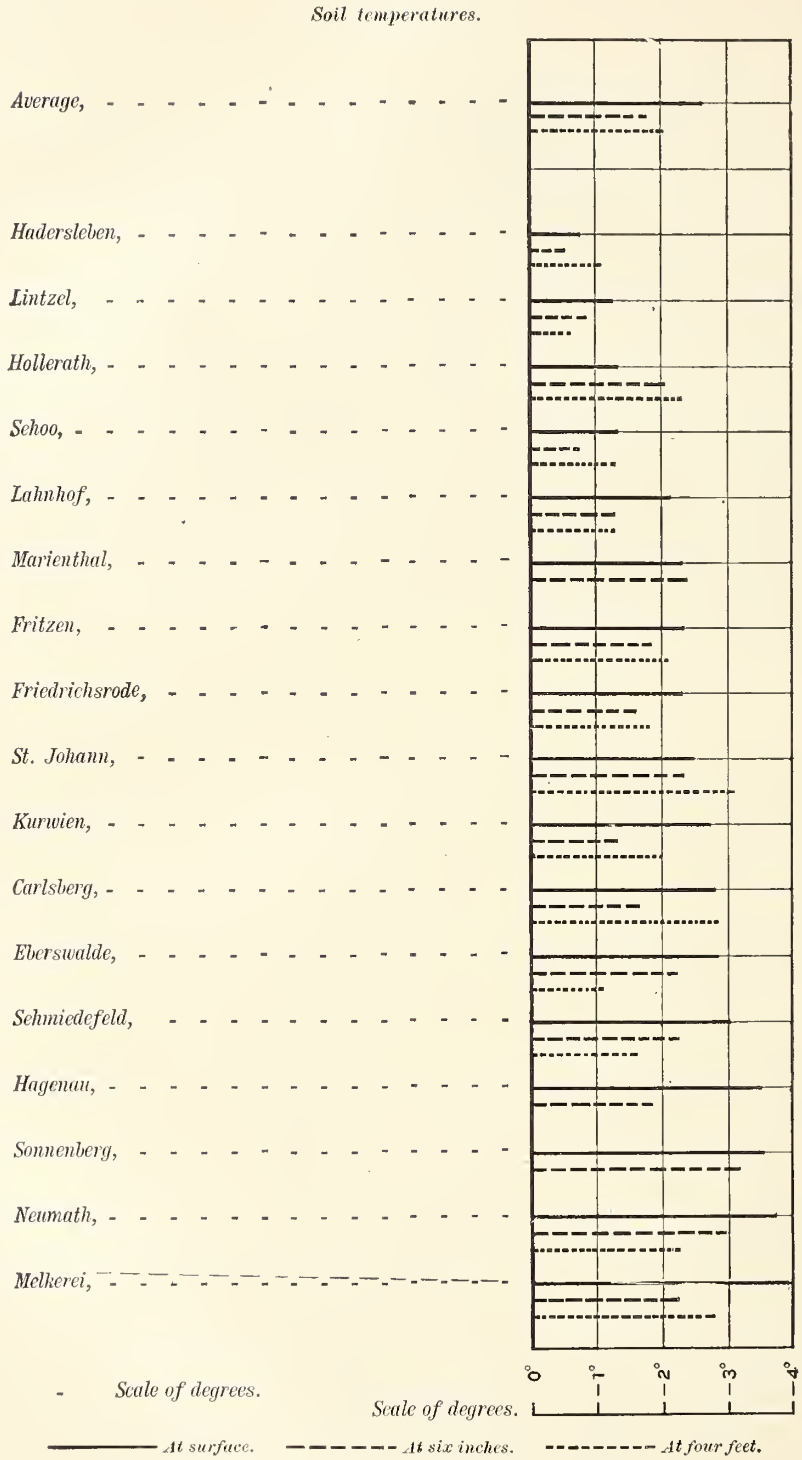


FIG. 42.—Differences of mean annual temperatures of soil (*W—O*).

Soil temperatures—Continued.

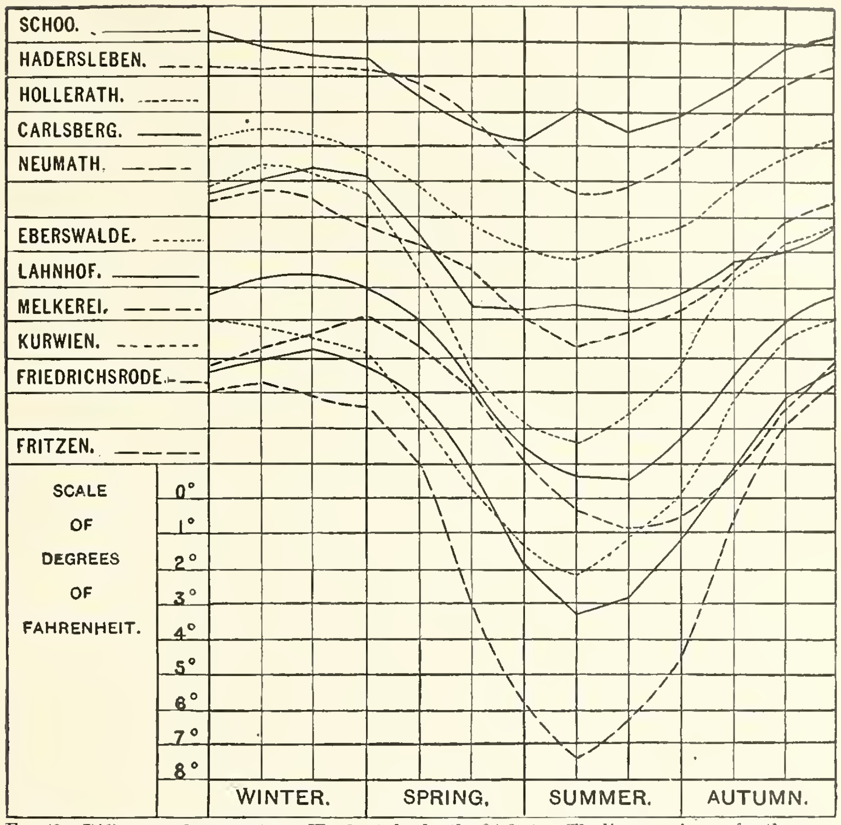


FIG. 43.—Difference of temperature (*W—O*) at the depth of 4 feet. (The line running under the name of a station is its zero line. The curve for the station is represented by the nearest broken, unbroken, or dotted line like that in the margin.)

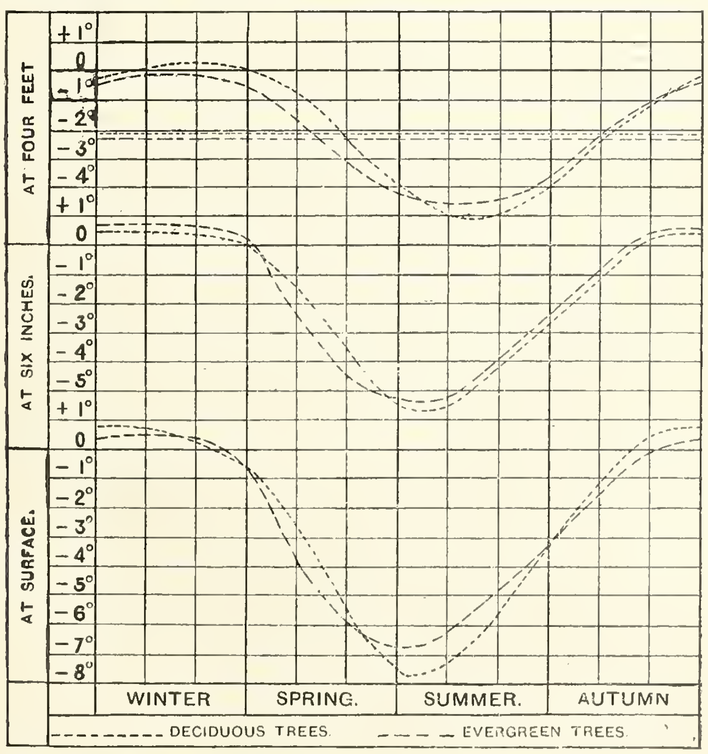


FIG. 44.—Differences of soil temperature (woods and open fields). Comparison of deciduous and evergreen trees (*W—O*).

Soil temperatures—Continued.

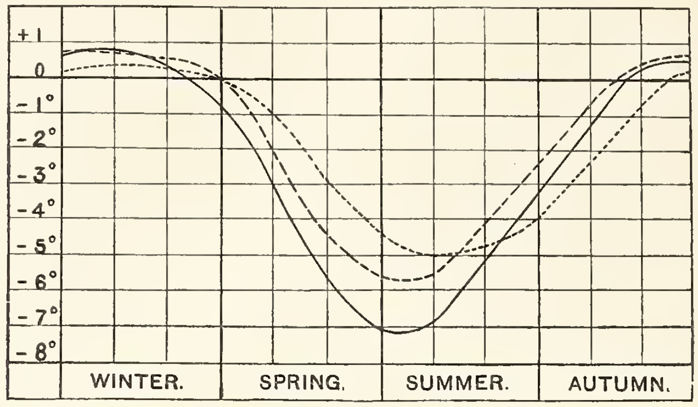


FIG. 45.—Difference of soil temperature ($W-O$), all stations—German observations.

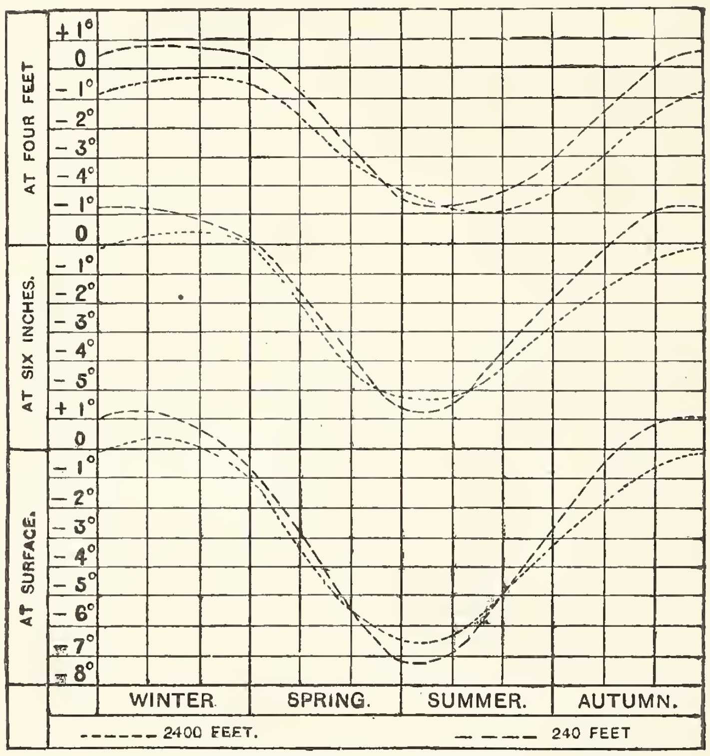
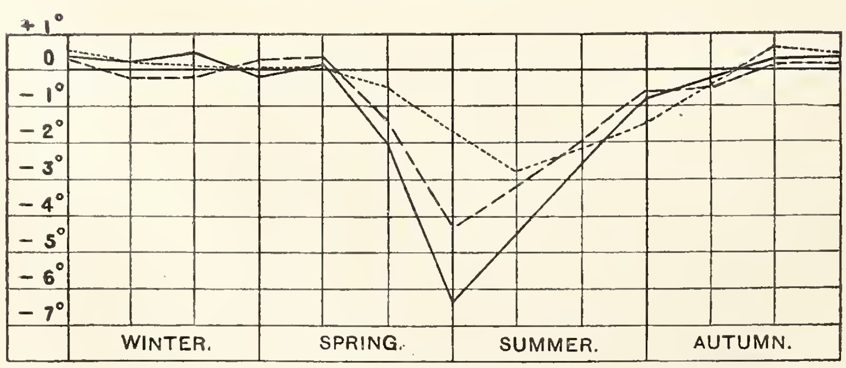


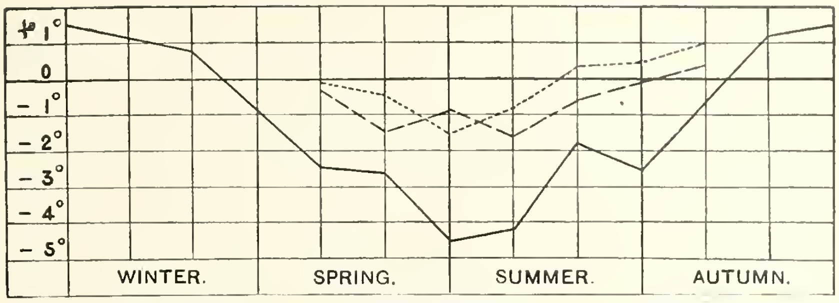
FIG. 46.—Differences of soil temperature (woods and open fields). Comparison of elevations above sea level ($W-O$).



———— *At surface.* — — — — — *At 6 inches below surface.* .... *At 4 feet below surface.*

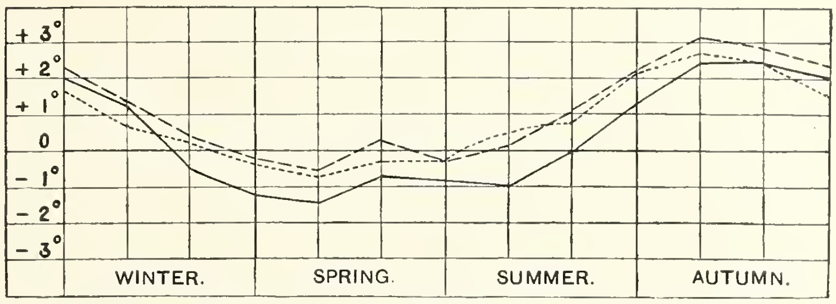
FIG. 47.—Differences of temperature for young trees, Lintzel Station, woods and open fields ($W-O$).

Soil temperatures—Continued.



———— *Average results.* — — — — *Results on loamy soil.* .... *Results on quartz soil.*

FIG. 48.—Effects of litter on soil temperature (littered surface—bare). (*W—O.*)



———— *Depth of 0.8 inch.* — — — — *Depth of 4.6 inches.* .... *Depth of 9.3 inches.*

FIG. 49.—Difference of soil temperature, under sod, and bare surface (sod—bare). Becquerel's observations.

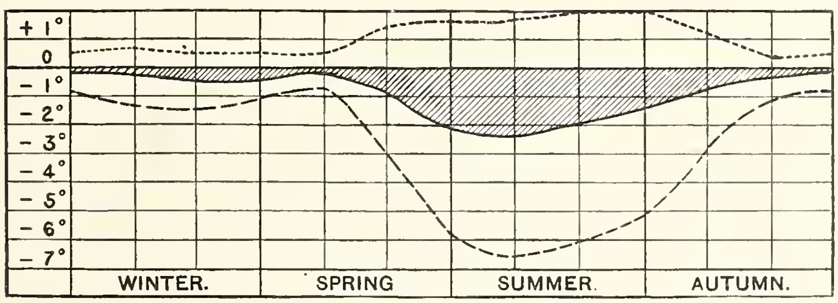


FIG. 50.—Under deciduous trees.

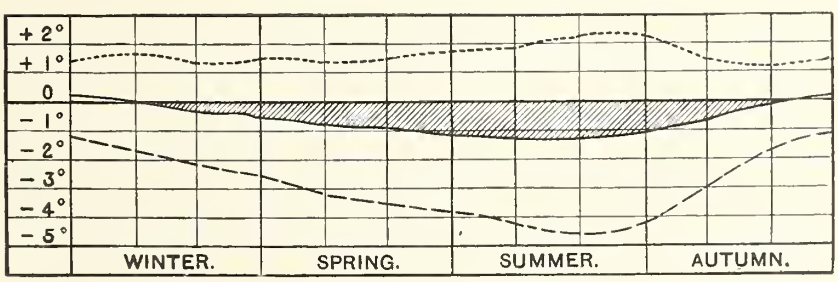
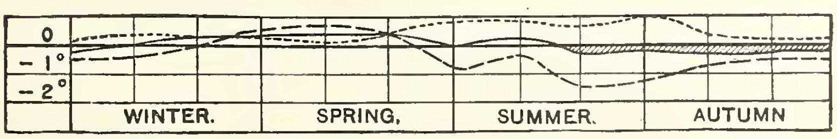


FIG. 51.—Under evergreen trees.



.... MINIMA. ———— MEAN. — — — — MAXIMA.

FIG. 52.—Under young forest (Lintzel).

Air temperatures in forests and open fields.

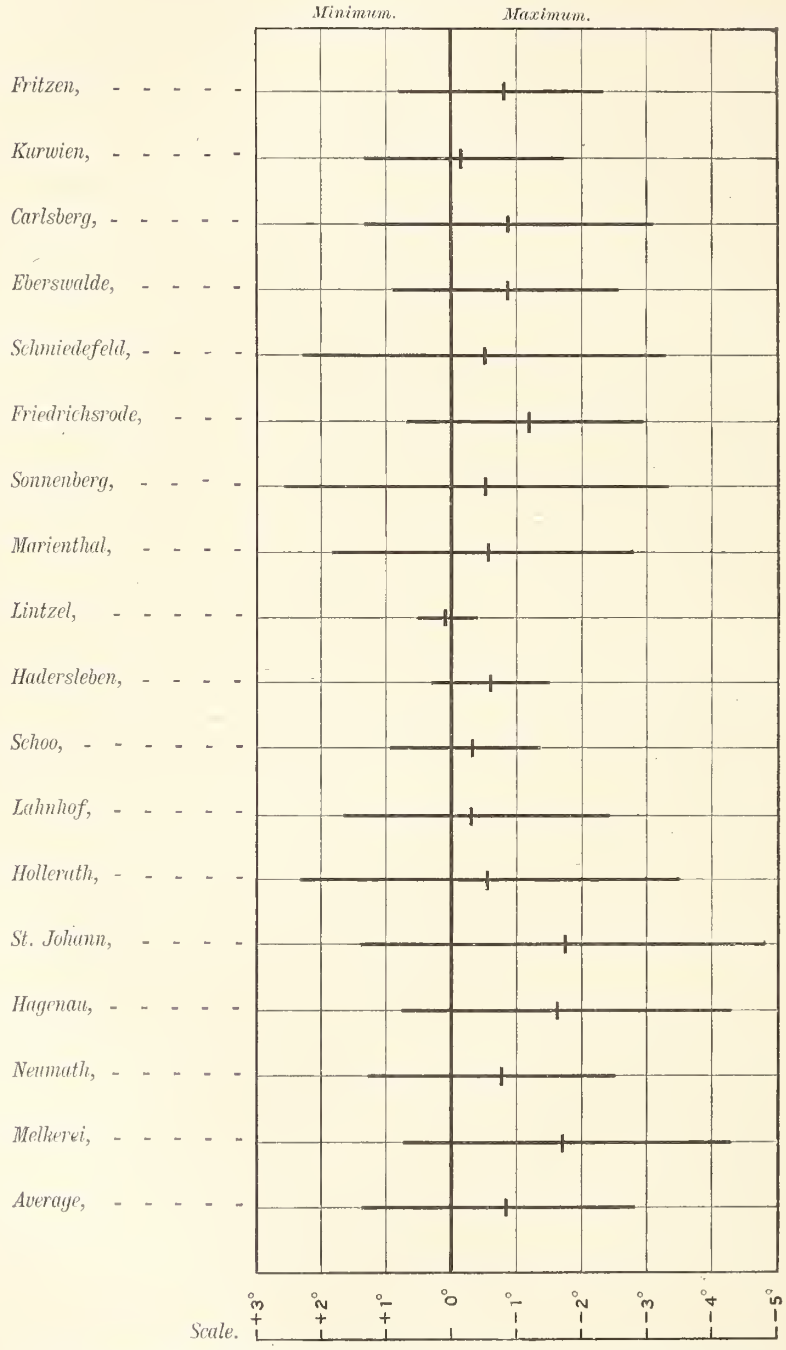


FIG. 53.—Forest air temperature differences (*W—O*). German stations. Mean annual (cross-bar), maxima (below zero line), minima (above zero line), and range (length of lines).

Air temperatures in forests and open fields—Continued.

............MINIMA. ——————MEAN. — — — — MAXIMA.

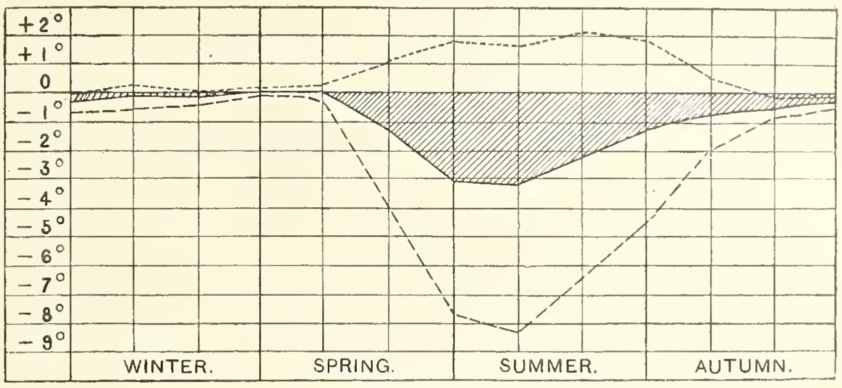


Fig. 54.—Friedrichsrode.

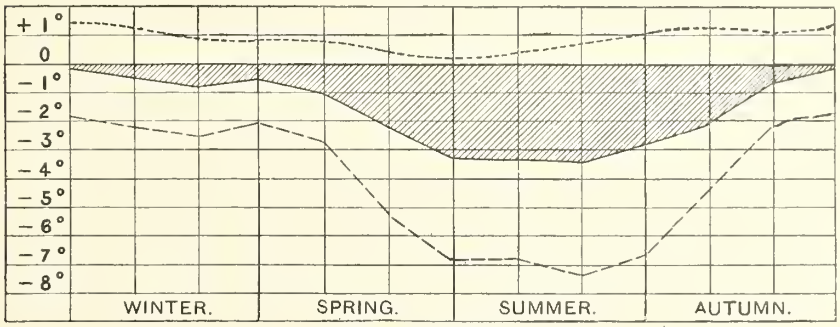


Fig. 55.—Hagenau.

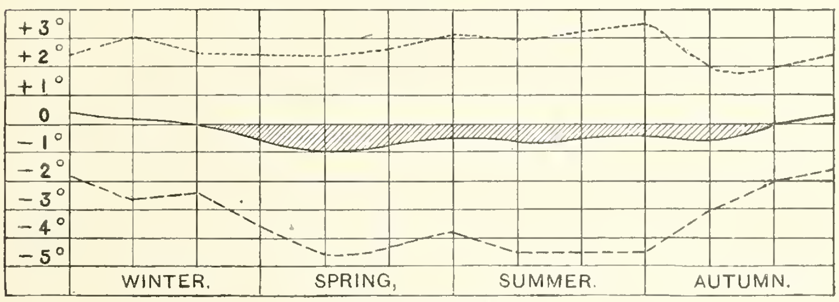


Fig. 56.—Sonnenberg.

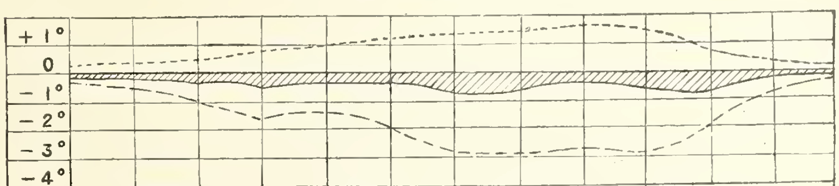


Fig. 57.—Eberswalde.

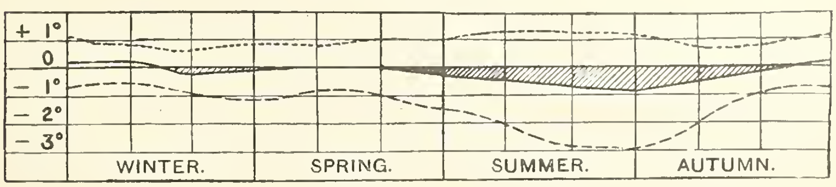


Fig. 58.—Schoo.

Air temperature in forests and open fields—Continued.

············MINIMA. ————MEAN. — — — — —MAXIMA.

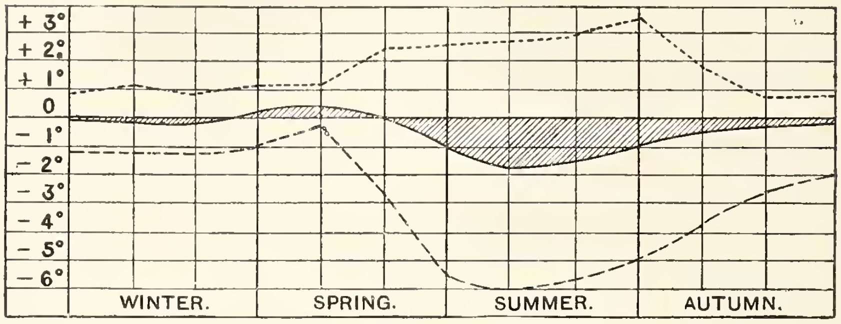


FIG. 59.—Marienthal.

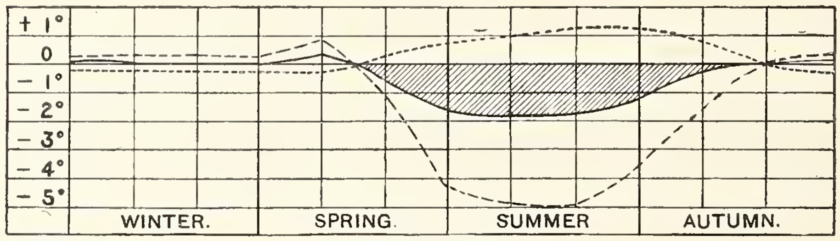


FIG. 60.—Hadersleben.

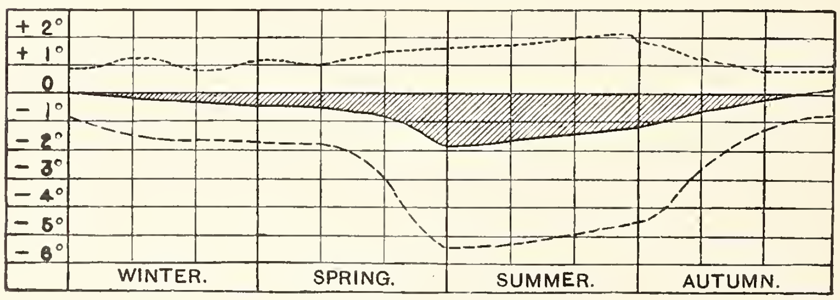


FIG. 61.—Average.

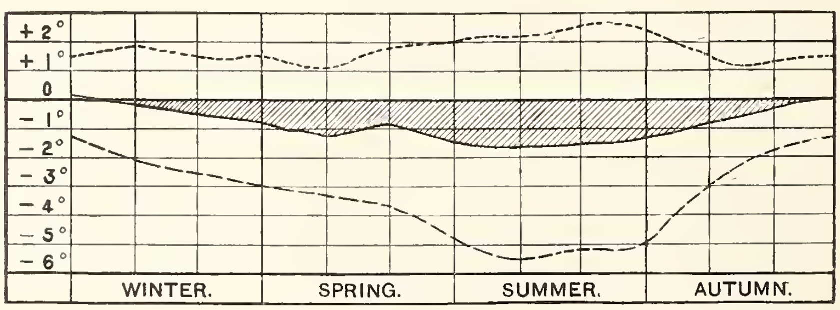


FIG.—62.—Elevated stations.

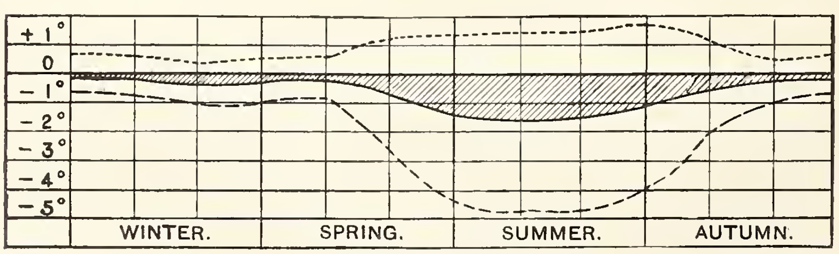


FIG. 63.—Near sea level.

Tree-top temperature differences, woods and open-fields.

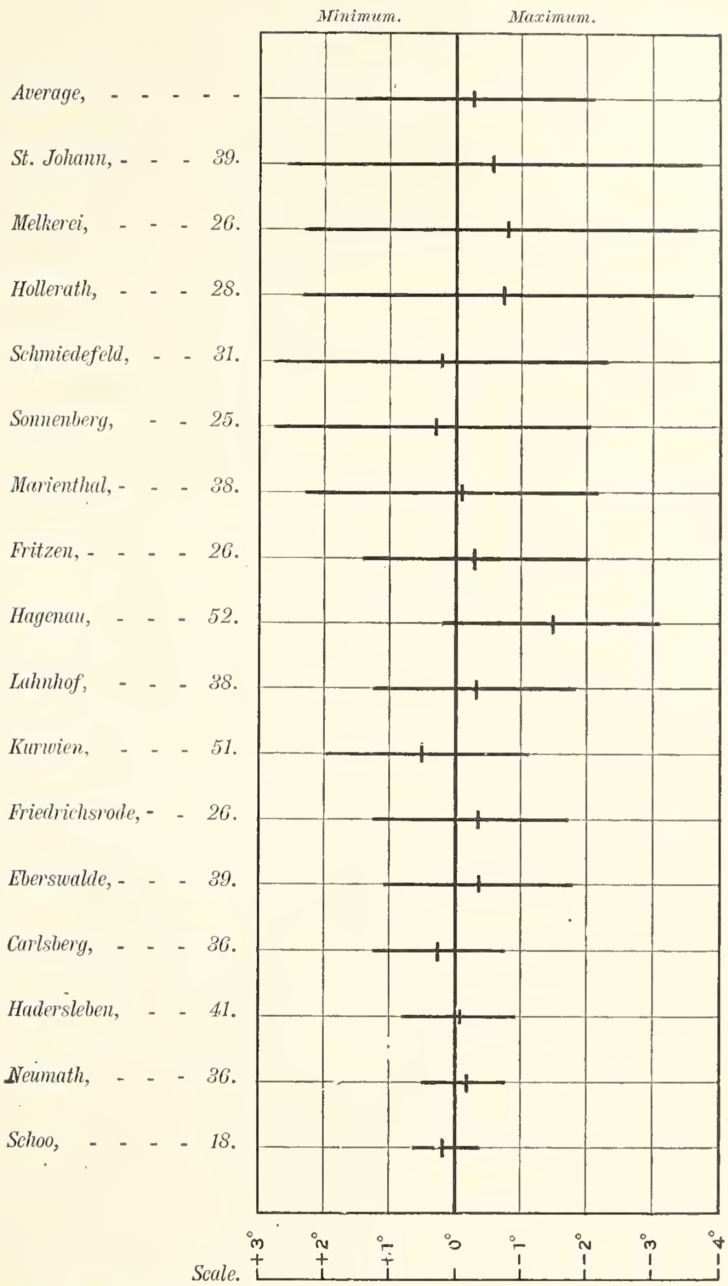


FIG. 64.—Forest temperature differences for the year at height of the tree top ($W-O$).

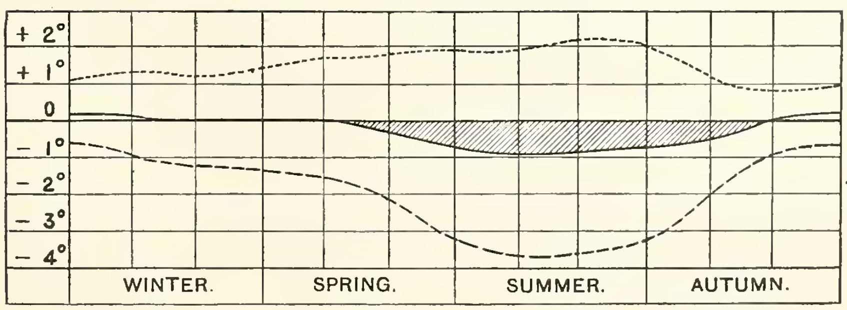


FIG. 65.—Average differences of tree-top temperature, sixteen German stations ($W-O$).

Tree-top temperature differences, woods and open fields—Continued.

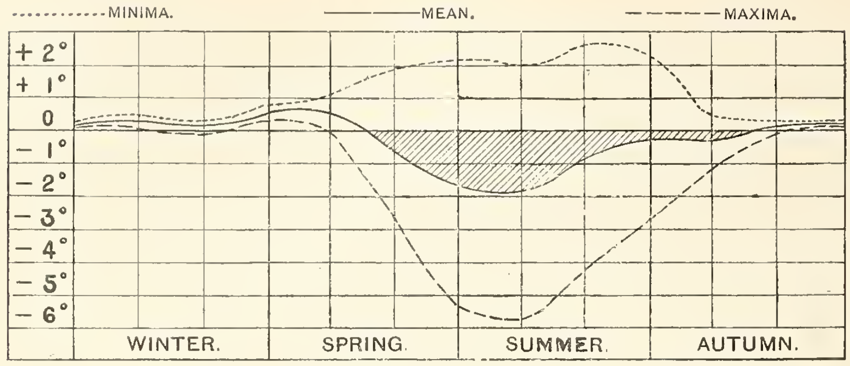


FIG. 66.—Friedrichsrode.

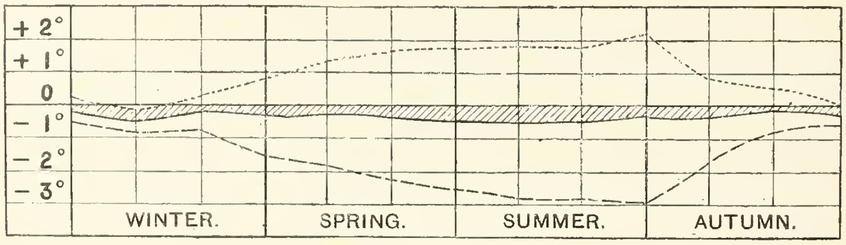


FIG. 67.—Eberswalde.

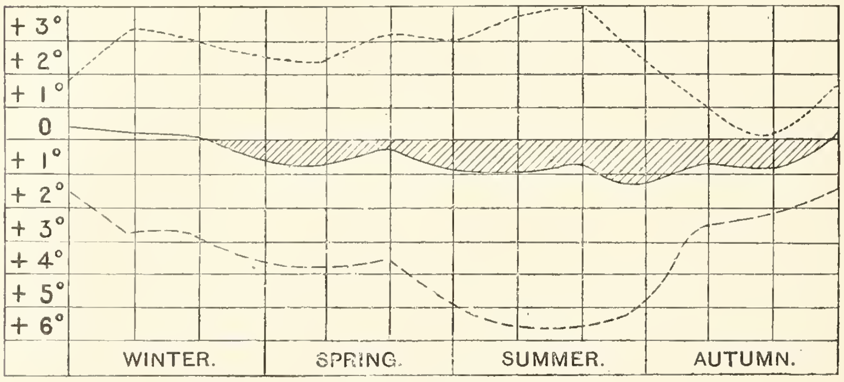


FIG. 68.—St. Johann.

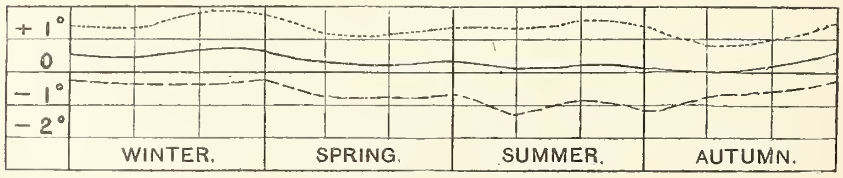


FIG. 69.—Carlsberg.

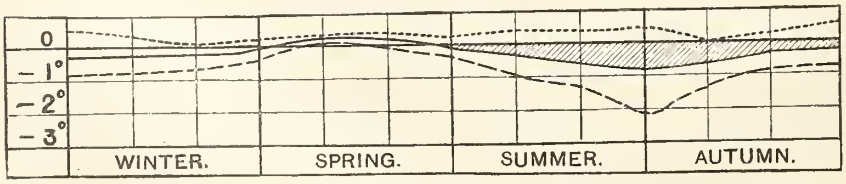


FIG. 70.—Schoo.

Tree-top temperature differences, woods and open fields—Continued.

............MINIMA. ———— MEAN. — — — — — MAXIMA.

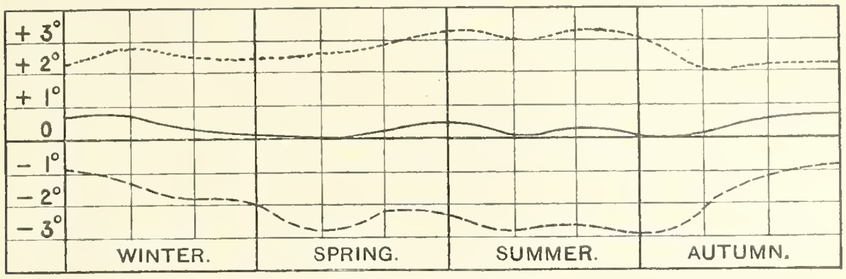


Fig. 71.—Sonnenberg.

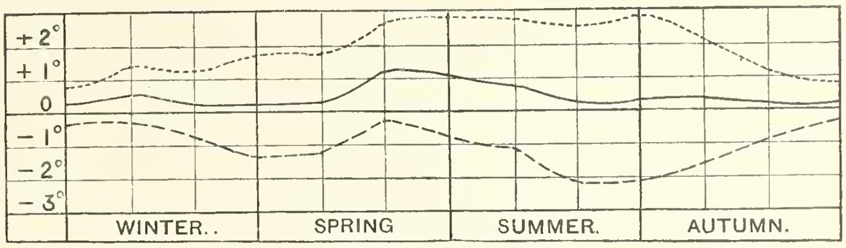


Fig. 72.—Kurwien.

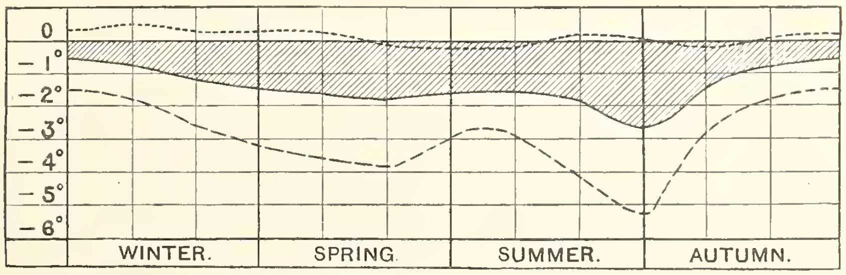


Fig. 73.—Hagenau.

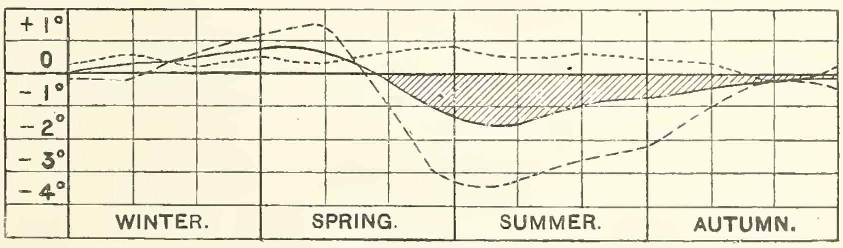


Fig. 74.—Neumath.

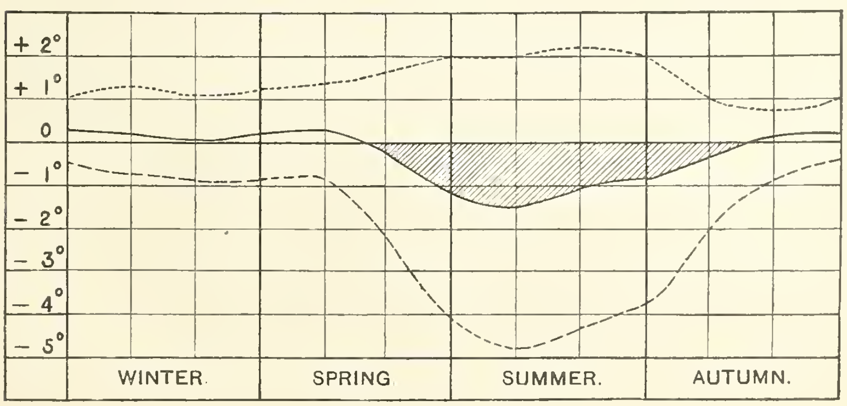


Fig. 75.—Deciduous trees.

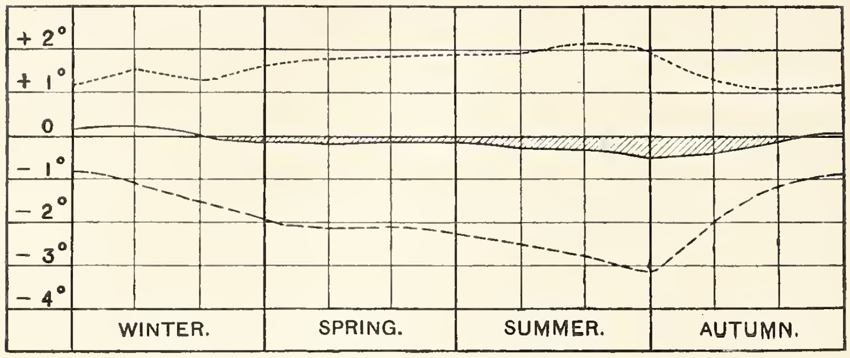
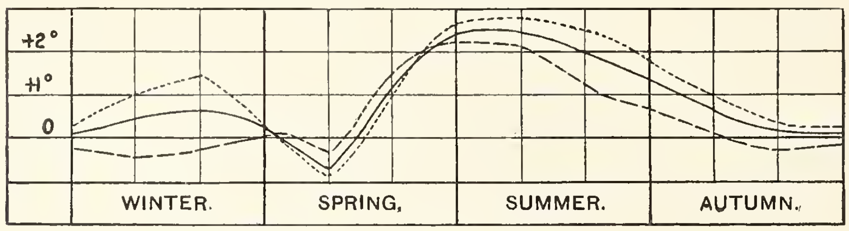
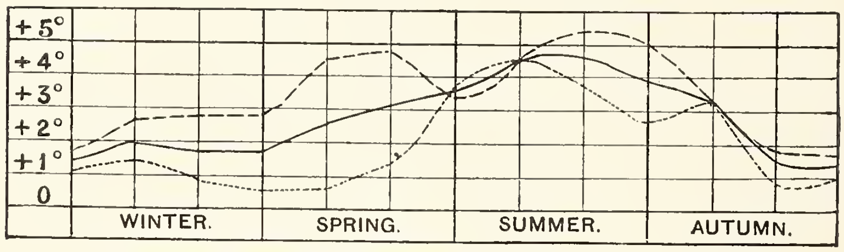


FIG. 76.—Tree-top temperature differences ($W-O$), evergreen trees.



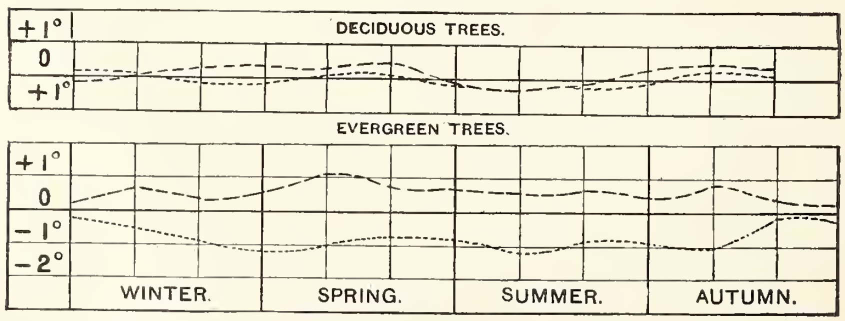
— — — — *Deciduous trees.* .... *Evergreen trees.* ———— *Average of all.*

FIG. 77.—Vertical temperature, gradient in woods, degrees Fahrenheit for 100 feet.



— —·— — EVERGREEN TREES., ——— AVERAGE OF BOTH. .... DECIDUOUS TREES.

FIG. 78.—Vertical temperature gradients from observations above trees.



.... MINIMA. ——— MEAN. — — — — MAXIMA.

FIG. 79.—Forest temperature, differences above trees—from Fautrat's observations.

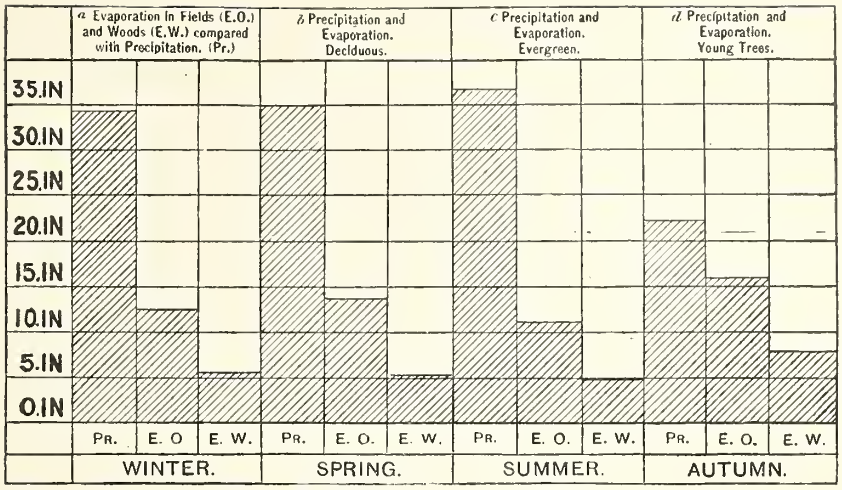


FIG. 80.—Evaporation and precipitation.

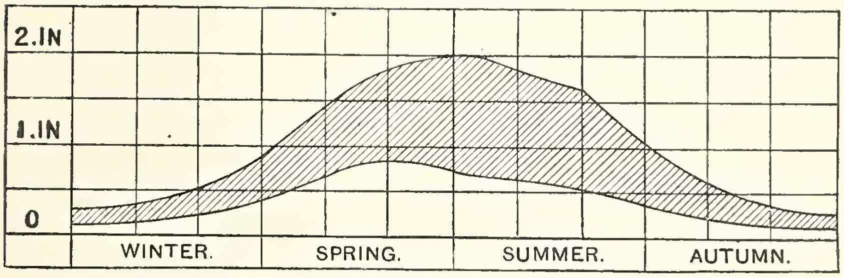


FIG. 81.—Monthly evaporation in the fields (upper curve) and woods (lower curve).

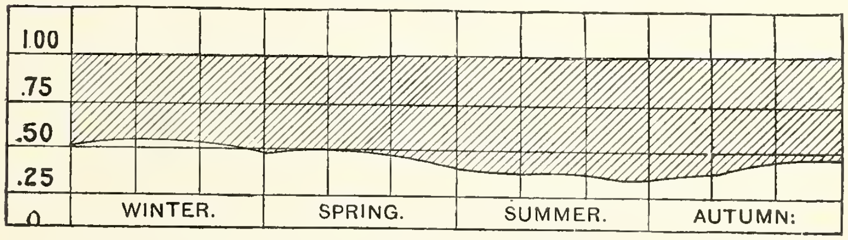


FIG. 82.—Percentage of evaporation in the woods as compared with that in open fields.

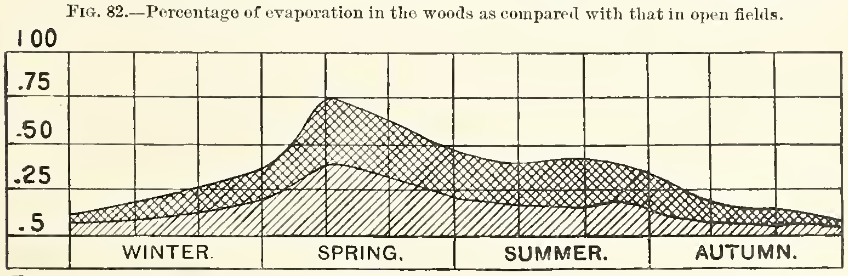


FIG. 83.—Ratio of evaporation from water surface in field (upper curve) and forest (lower curve) to precipitation (top line).

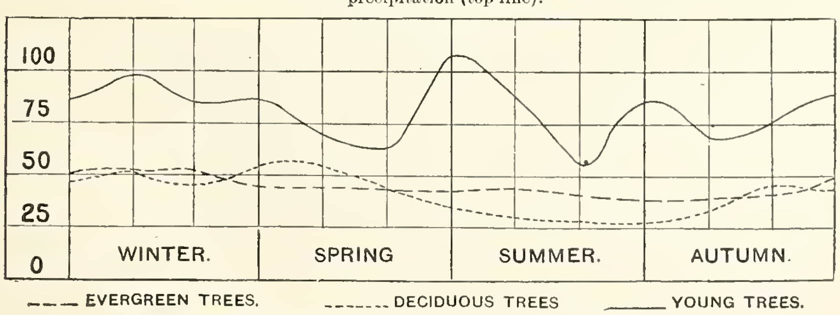


FIG. 84.—Percentage of evaporation in woods to that in the open air.

I. THE WORK IN TIMBER PHYSICS IN THE DIVISION OF FORESTRY.

By Filibert Roth,

Late Assistant in the Division of Forestry.

Historical.

As in the case of other materials, exact investigation of the properties of wood did not begin until the latter part of the eighteenth and the beginning of the nineteenth century, when Girard Buffon and Duhamel du Monceau in France, and Peter Barlow, the nestor of engineering in England, laid the foundation for this inquiry by devising suitable methods and working out correct formulæ for the computation of the results. As might be expected, the results of this pioneer work, particularly that of the French investigators, were often contradictory, and have to-day little more than historical value.

Subsequently our knowledge of wood in general, and that of European species in particular, was increased by a number of experimenters. Among these, Chevandier and Wertheim in France, and Nördlinger in Germany, stand out conspicuous. Unfortunately, their apparatus was crude and, in the case of the French workers, the series was too small to satisfy so complicated a problem, while Nördlinger was obliged to content himself with small and few specimens, owing to a want of proper equipment.

In England considerable money was expended from time to time both by Government and private enterprise, but the eagerness of making the matter as practicable as possible led, unfortunately, to much testing of large sizes and to the employment of insufficient (because unsystematic) methods, so that such extreme experiments as those of Fowke and others have really neither furthered science nor helped the practice. In this country the engineering world for a long time relied largely on the results of European testing, and the wood consumers in general depended on a meager accumulation of experience and crude observation concerning most of the fine array of valuable and abundant kinds of timber offered in our markets.

Ignorance and prejudice had their way. Chestnut oak was pronounced unfit for railway ties, and thus millions of logs were left rotting in the woods, though this prejudice had not a single fair trial to support it. "Bled" longleaf, or Georgia pine, was considered weaker and less durable, millers and dealers were obliged to misrepresent their goods, causing unnecessary loss and litigation, and yet there existed not a single record of a properly conducted experiment to substantiate these views. Gum was of no value, Southern oak was publicly proclaimed as unfit for carriage builders, and the views as to the usefulness of different timbers were almost as numerous as the men expounding them.

The engineering world was the first to realize this deficiency, and men like Hatfield, Lanza, Thurston, and others attempted to replace the few antiquated and unreliable tables of older text-books by the results performed on American woods and with modern appliances.

In addition to these efforts of engineers, Sharples, under Sargent's direction, in his great work for the Tenth Census of 1880, subjected samples of all our timber trees to mechanical tests, but, since in these tests only a few select pieces represented each species, the engineering world never ventured to use the results. As regards the rest of the wood testing in our country, it may be said that it generally possessed two serious defects: (1) the wood was not properly chosen, and (2) the methods of testing were defective, especially with respect to the various states of seasoning, wood being tested in almost every state from green to dry, without distinction. This is the more

remarkable since the important influence of moisture was recognized and emphasized by both French and German experimenters more than forty years ago.[1]

These facts were fully appreciated by the engineers of our country, as is well shown by the numerous, often emphatic, approvals and recommendations of the timber-physics work undertaken by the Division of Forestry, and by the eagerness with which wood consumers generally seized on all information of this kind as fast as the Division of Forestry could supply the same.

SOUTHERN AND NORTHERN OAK.

Though fully planned before, the work in timber physics was really begun in order to decide an important controversy as to the relative value of Southern and Northern grown oak.

A representative committee of the Carriage Builders' Association had publicly declared that this important industry could not depend upon the supplies of Southern timber, as the oak grown in the South lacked the necessary qualities demanded in carriage construction. Without experiment this statement could be little better than a guess,[2] and was doubly unwarranted, since it condemned an enormous amount of material, and one produced under a great variety of conditions and by at least a dozen different species of trees, involving, therefore, a complexity of problems difficult enough for the careful investigator, and entirely beyond the few unsystematic observations of the members of a committee on a flying trip through one of the greatest timber regions of the world.

A number of samples were at once collected (part of them supplied by the carriage builders' committee) and the fallacy of the broad statement mentioned was fully demonstrated by a short series of tests and a more extensive study into structure and weight of these materials. From these tests it appears that pieces of white oak from Arkansas excelled well-selected pieces from Connecticut both in stiffness and endwise compression (the two most important forms of resistance).

Results of tests on Northern and Southern white oak made in Washington University Laboratory, St. Louis, Mo., by Prof. J. B. Johnson, 1889.

Test piece.		Bending and cross breaking. Size of test piece 1⅜ by 1⅜ by 24.						Compression.				Shearing.	
		Stiffness.		Ultimate strength.		Resistance to shock.		Endwise.		Transverse.		Longitudinal.	
Where procured.	No.	Range No.	[3]Modulus of elasticity, pounds per square inch.	Range No.	Modulus $\frac{3.\ W.\ L.}{2.\ b.\ h^2}$ pounds per square inch.	Range No.	Modulus inch-pounds per cubic inch.	Range No.	Modulus pounds per square inch. Size 1⅜ by 5 inches.	Range No.	Modulus pounds per square inch.	Range No.	Modulus pounds per square inch.
A. a. I	1	9	990, 000	3	13, 760	4	59	6	6, 160	1	3, 400	3	1, 375
	2	5	1, 280, 000	1	18, 500	1	92	7	5, 480	3	3, 100	1	1, 560
Average	......	3	1, 135, 000	1	16, 130	1	76	3	5, 820	1	3, 250	1	1, 468
A. b. II	3	6	1, 120, 000	8	12, 300	6	47	11	4, 740	7	2, 500	6	....
	4	10	920, 000	5	12, 700	5	55	9	4, 980	4	2, 800	7	1, 225
Average	......	4	1, 020, 000	3	12, 500	3	51	5	4, 860	2	2, 650	3	1, 225
	5	11	850, 000	9	11, 400	2	83	8	5, 230	5	2, 700	4	1, 375
	6	7	1, 140, 000	7	12, 300	7	45	10	4, 820	8	2, 500	2	1, 540
Average	......	5	995, 000	5	11, 850	2	64	4	5, 025	3	2, 600	2	1, 458
B		Size: 1⅜ by 1⅜ by 18 inches.						Size: 1⅜ cube.					
	7	3	1, 570, 000	6	12, 380	9	27	4	6, 800	11	2, 000	10	860
	8	8	1, 100, 000	2	14, 690	3	82	1	7, 800	2	3, 200	5	1, 260
	9	4	1, 385, 000	11	11, 240	11	19	5	6, 800	9	2, 300	11	825
Average	......	2	1, 351, 667	2	12, 770	4	43	2	7, 133	4	2, 500	5	982
	10	1	1, 653, 000	4	13, 030	8	30	3	6, 900	6	2, 600	8	1, 050
	11	2	1, 581, 000	10	11, 590	10	22	2	7, 700	10	2, 100	9	940
Average	......	1	1, 617, 000	4	12, 310	5	26	1	7, 300	5	2, 350	4	995

[1] For a more complete history see Bulletin 6 of Division of Forestry.

[2] See Report of the Division of Forestry, 1890, page 209.

[3] Young's modulus of elasticity: $E = \frac{W.\ L.^3}{4\ D.\ b.\ h.^3}$ where $\begin{cases} W. = \text{total load at center in pounds} \\ L. = \text{length in inches.} \\ D. = \text{deflection in inches.} \\ b. = \text{breadth in inches.} \\ h. = \text{height in inches.} \end{cases}$

Description of test material and results of physical examination.

Notation as to station, site, and tree	A. a. I. Connecticut upland.	A. b. II. Connecticut lowland.	B. Arkansas.
Number of test piece	1.	3.	
Exposure in tree	North.	Southwest.	
Height in tree	"Butt cut."	"Butt cut."	
Position in tree (with reference to periphery)	Not known.	Not known.	
Size of test material:			
Length	4	4	
Breadth	$1\frac{5}{8}$ inch.	$1\frac{5}{8}$ inch.	
Depth (measured across rings)	$1\frac{5}{8}$ inch.	$1\frac{5}{8}$ inch.	
Number of rings			Not specified.
Width of rings (average)	2.7 millimeters.	1.5 millimeters.	
Summer wood as a whole	80 per cent.	54 per cent.	
Firm bast tissue	60 per cent.	37.5 per cent.	
Space lost by large vessels	14.7 per cent.	24.9 per cent.	
Moisture conditions when tested	Nearly seasoned.	Half seasoned.	
Density	.84	.77	

These particular tests can hardly settle definitely any question. Samples 1 and 2 being selected stock, second growth, can not be used for comparison with samples of B, except to show that for stiffness the unselected Southern stock is superior to the best Northern growth, as also in resistance to endwise compression. The samples 3, 4, 5, and 6 are probably more nearly comparable to samples of B, and here we find the Southern oak very much superior, not only in stiffness and columnar strength, but also in ultimate cross-breaking strength, while for resistance to shock, at least one sample of Southern oak is superior to three samples of forest-grown Northern, and even to one of the best Northern second growth. This piece (No. 8) exhibits, altogether, qualities which render the verdict tenable that Southern oak is not necessarily inferior to Northern oak in any of its qualities.

Beyond this it would not be safe to use these figures for generalizations.

In 1888 the really first beginning in timber physics was made in the form of a preliminary physical and structural examination of a set of trees representing the more important lumber pines of the South and of the lake region, as well as of bald cypress. A comprehensive plan was fully worked out and the mistakes of former methods were carefully avoided. In 1891 a more extensive study of the four great Southern timber pines, the longleaf, Cuban, loblolly, and shortleaf, was begun, and the material was at the same time collected in such a manner as to enable a detailed inquiry into the relative merits of timber bled or tapped for turpentine as compared with unbled timber.

The trees were collected by Dr. Charles Mohr, of Mobile, Ala., an acknowledged authority on the botany of the region, and thus a correct identification was assured. Of each tree entire cross sections as well as the intervening logs were utilized, the former being subjected to examinations into their specific weight (the acknowledged indicator of many valuable technical properties), into the amount of moisture contained, into the shrinkage consequent on drying, and into the structural peculiarities, particularly those structural features which are readily visible and may be utilized in practice for purposes of timber inspection.

The logs were sawed and tested according to definite plans in the well-equipped test laboratory of the Washington University, St. Louis, Mo., under the direction of Prof. J. B. Johnson, a recognized authority in engineering. The first series of test results are embodied in Bulletin No. 8 of the division, where the strength values for the longleaf pine are fully tabulated and discussed. So eagerly was this bulletin sought by wood consumers, that an edition of 5,000 copies was exhausted in a short time.

BLED AND UNBLED PINE.

In addition, this series of tests together with an extensive chemical analysis and physical and structural examination of material from unbled and bled trees, as well as from trees bled and abandoned for five years, re-enforced by an extended study of bled and unbled timber at various points of manufacture, proved conclusively that the discrimination against bled timber was unwarranted, since the bled timber was neither distinct in appearance, behavior, nor strength.

To avoid error in so important a matter, and also for a comparison of the three most important turpentine trees—the Cuban and longleaf with the loblolly pine—the extensive chemical analyses of Dr. M. Gomberg, of the Michigan University, were repeated and extended by Mr. O. Carr, of the Chemical Division of the Department of Agriculture. This series of additional chemical

analyses fully substantiated Dr. Gomberg's work, so that it was safe to announce that: (1) Bled timber is as strong as unbled timber; and (2) that it contains the resinous substances in the same amounts and similarly distributed as the wood of unbled timber, so that it seemed to follow as a simple corollary that bled timber is also as durable as unbled, and hence equal to the latter in every respect.

The importance of this fact was quite fully realized. Trautwine, in his standard work, the Engineers' Pocketbook, at once placed the fact on eminent record, and the lumbermen of the South, as well as all trades journals, spread the welcome news in every paper and at every opportunity.

The work of Mr. Gomberg in determining the distribution of the resin through the different parts of the tree is unique in method and classical in its clear scientific procedure and statement. Since the publication in which it first appeared was at once exhausted, it appears proper to reproduce it in full, leaving out only a few tables, as a part of the most valuable work in timber physics performed under direction of the Division of Forestry:

A Chemical Study of the Resinous Contents and their Distribution in Trees of the Longleaf Pine Before and After Tapping for Turpentine.

[By M. Gomberg.]

Botanists tell us that resins are produced by the disorganization of cell walls and by the breaking down of starch granules of cells. Chemists believe that resins are oxidation products of volatile oils, the change being expressed by formula as follows: $2C_{10}H_{16}+3O=C_{20}H_{30}O_2+H_2O$.

Whatever view be correct,[1] one thing is certain, and that is that the formation of either resins or essential oils requires the presence in the tree of those peculiar conditions which we call vital. The tree must live, must be active, must assimilate carbon dioxide and imbibe moisture, in order that oil of turpentine and rosin be formed.

The heart of the tree is the dead part of it. It does not manufacture any turpentine. A part of the oleoresin in it had been formed when the heartwood was yet sapwood, and remained there after the change from sap to heart had taken place. It is also probable that the heart of the tree acts as a storehouse in which there is deposited a portion of the oleoresin formed in the leaves and sap.

When a tree is tapped for turpentine there are two possible changes that might be supposed to take place: (1) The tree may be considered as placed in a pathological condition, when it will strive to produce a larger amount of oleoresin in order to supply the amount removed. In a few years the energy of the tree will be exhausted and the amount freshly supplied will fall far below the amount of oleoresin drawn off by the tapping. The tapping will then have to be discontinued. The oleoresin in the heartwood will in this case remain untouched. (2) The oleoresin previously stored away in the heart might, by some unknown means and ways, also be directed toward the wound.

If the first change takes place then, the tapping will have little effect upon the chemical composition of the heartwood. If, however, the second condition prevails during tapping, then of course the heartwood will be seriously affected for some time after tapping, and will contain a much smaller amount of oleoresin than it contained before tapping. Moreover, the tapping may affect not only the amount of oleoresin, but also the quality of the new product and the relative distribution of volatile products.

For this reason the chemical side of the problem has been approached by parallel analyses of tapped or untapped trees for their relative amounts of turpentine. It was hoped that by a large series of analyses an average might be obtained showing whether tapped and untapped trees differ from each other in that respect.

CHEMICAL COMPOSITION OF TURPENTINE.

Under the name of turpentine is known an oleoresinous juice produced by all the coniferous trees in greater or less amount. It is found in the wood, bark, leaves, and other parts of the trees. It flows freely as a thick juice from the incisions in the bark. It consists of resin or resins

[1] The one view does not exclude the other.

dissolved in an essential oil; the latter is separated from the former usually by distillation with steam.

There are many varieties of turpentine, corresponding to the different varieties of coniferæ, but only three are commercially important, as they are the source of the three principal oils of turpentine.

(1) The turpentine of *Pinus pinaster* (syn. *P. maritima*), collected in the southern departments of France around Bordeaux. From it is obtained the French turpentine, which yields 25 per cent of volatile oil.

(2) The turpentine from *Pinus palustris*, *P. tæda*, *P. heterophylla*, collected in the southern sea-bordering States from North Carolina to Texas. From them, principally from the first source, is obtained the English or American oil of turpentine, which yields 17 per cent of volatile oil. Formerly the *P. rigida* was also worked for turpentine in the North Atlantic States, but it is now exhausted.

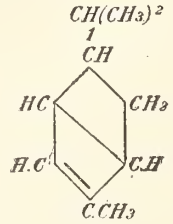
(3) The turpentine from *Pinus laricio* var. *austriaca*, collected mainly in Austria and Galicia. From it is obtained the German turpentine oil, which yields 32 per cent of volatile oil.

The Russian oil of turpentine is obtained from *Pinus silvestris* and *Pinus ledebourii*, by the direct distillation of the resinous wood, without previously collecting the turpentine. It is said to be identical with the German oil of turpentine, but more variable, as it contains products of destructive distillation, both of wood and rosin.

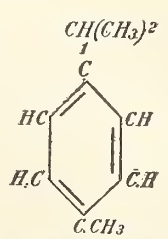
The turpentines from the different sources differ from each other—(1) in their action upon polarized light, (2) in the relative amounts of volatile oil they yield on distillation with steam, and (3) in the nature of the volatile oils they contain.

Colophony.—The rosin in the different varieties of turpentine is practically the same. It is known as common rosin or colophony.[1] It consists chemically of a mixture of several resin acids and their corresponding anhydrides. The chief constituent is abietic anhydride, $C_{44}H_{62}O_4$, abietic acid being $C_{44}H_{64}O_5$. The crystals that are noticed in crude turpentine are the free abietic acid; on melting the thick turpentine, or on distilling the volatile oil, the acid is changed to the anhydride. Colophony is nonvolatile, tasteless, brittle, has a smooth shining fracture, sp. gr. about 1.08. It softens at 80° C., and in boiling water melts completely at 135° C.

The volatile oil.—The second principal constituent of turpentines are the volatile oils. The chief ingredient of the three turpentine oils is a hydrocarbon of the same composition, $C_{10}H_{16}$; nevertheless the three oils have distinct hydrocarbons differing from each other in physical if not in chemical properties. The empirical formula of the hydrocarbon is $C_{10}H_{16}$, and according to the latest researches of Wallach[2] it has the following structural formula:



thus being a dihydro-para-cymene, paracymene being $C_{10}H_{14}$,



[1] Colophon, a city of Iconia, whence rosin was obtained by the Greeks.
[2] Ann. Chem. (Liebig), 239, 49; Ber. d. Chem. Ges., 24, 1545.

The position of this particular terpene, pinene, will be best seen from the general classification of terpenes taken from Wallach.[1]

I. *Hemiterpenes* or *pentenes* of the formula C_5H_8.
II. *Terpenes* or *dipentenes* of the formula $C_{10}H_{16}$.
(1) *Pinene*, obtained from many varieties of turpentine.
(2) *Camphene*, obtained artificially from camphor.
(3) *Fenchene*, obtained artificially from fenchone, a constituent of many fennel oils.
(4) *Lemonene* occurs in orange-peel oil, in oils of lemon, bergamot, cuminin, etc.
(5) *Dipentene*, obtained artificially from pinene. Occurs in Russian and Swedish turpentine.
(6) *Sylvestrene* occurs in Russian and Swedish turpentine.
(7) *Phelandrene* occurs in the oils of bitter fennel and water fennel, elemi, eucalyptus.
(8) *Terpinene* occurs in oil of cardamom.
(9) *Terpinolene*, only slightly known.
III.—*Polyterpenes*, of the formula $(C_5H_8)_n$, as cedrenes $C_{15}H_{24}$ caoutchouc $(C_5H_8)_n$, etc.

The hydrocarbon of the American and French oils of turpentine is pinene. It is dextrorotatory when obtained from the American turpentine oil, and is known as austro-terebinthene or australene; lævo-rotatory when obtained from the French turpentine oil, and is known as terebinthene. Otherwise the two hydrocarbons agree entirely in specific gravity, boiling point, and behavior toward chemical reagents.

The hydrocarbon of the Russian oil of turpentine is sylvestrene. It is dextro-rotatory, and has a higher boiling point than pinene. The latter boils at 155° to 156° C., the former at 175° to 178° C.

But even the turpentine oils of high grade as found on the market do not consist of pure pinene; especially is this true of ordinary oil of turpentine, which is obtained from the cruder turpentine by a single distillation with steam. Different samples vary from one another considerably in their specific rotatory power as well as their boiling point.

American oil of turpentine has a density of 0.864° to 0.870°. According to Allen[2] it begins to boil at a temperature between 156° and 160° C., and fully passes over below 170° C. "A good sample of rectified American oil will give 90 to 93 per cent of distillate below 165°, the greater part of which will pass over between 158° and 160°",[3] while in the experience of J. H. Long,[4] "In the examination of a large number of pure commercial samples of turpentine oil it was observed that the boiling point was uniformly at 155° to 156°, and that 85 per cent of the samples distilled between 155° and 163°. The distillation is practically complete below 185° C."

Then, again, as found by Long, the vapor densities of many samples of oil are too high to allow the formula $C_{10}H_{16}$ for the entire oil. Fractions of different boiling points show different degrees of specific rotation. All this would indicate that ordinary turpentine oil contains hydrocarbons heavier than pure pinene, $C_{10}H_{16}$. They are probably either isomeric with pinene, but of a higher boiling point, or may belong to the polyterpenes.

Still less do we know of the source of these hydrocarbons. Whether they are produced by the tree simultaneously with pinene, and are therefore to be found in the oleoresin or whether they are all or in part produced by external agencies after the turpentine has been dipped can not be answered. Probably the formation of these other hydrocarbons takes place in both ways spontaneously in the tree and by some influences outside the tree.

Indeed, all terpenes have this property in common that they easily undergo change, from optically active to inactive, from hemiterpenes to terpenes and polyterpenes. The change can be brought about either by heat alone, or by heating the terpenes with salts or acids. So, when a sample of American turpentine oil of +18.6° was heated to 200° C. for two hours it showed an opposite rotation of —9.9°.[5] Pinene heated to 250° to 300° C. is converted into dipentene CH, boiling at 175°, and a hydrocarbon CH, boiling at 260° C.

These illustrations will suffice to show that the transformation of pinene into isomeric and heavier hydrocarbons may occur, at least partially, after the turpentine has been removed from the tree.

[1] Ann. Chem. (Liebig), 227, 300; Ber. d. Chem. Ges., 24, 1527.
[2] Allen, Com. Org. Anal., 2, 437.
[3] Allen, Com. Org. Anal., 2, 441.
[4] Jour. Anal. and Appl. Chem., 6, 5.
[5] Muspratt's Chemie, 4th ed., 1, 153.

The crude turpentine from *Pinus palustris*, or long-leaf pine, is thus made up of—

(1) Rosin, 75 to 90 per cent; mostly abietic anhydride.
(2) Australene, 25 to 10 per cent; boils at 155° to 156° C.
(3) Some other terpenes of $C_{10}H_{16}$; small portions; kind not known.
(4) Some polyterpenes of $(C_5H_8)_n$; small portions; kind not known.
(5) Cymene (?) $C_{10}H_{14}$; small portions, if any; boils at 175° to 176° C.
(6) Traces of formic and acetic acids; produced probably by atmospheric oxidation during collection of turpentine.

ANALYTICAL WORK.

As both the rosin and the volatile oil are easily soluble in chloroform, ether, carbon disulphide, etc., their separation from wood by any of the above solvents would appear to be an easy matter. But an exact quantitative determination of the volatile oil presents considerable difficulties, and for these reasons: (1) Wood can not be dried free from moisture without driving off some of the volatile hydrocarbons; (2) the ether extract can not be freed entirely from either without some loss of the volatile oil.

If a weighed quantity of wood shavings is exhausted with either, the residue dried at 100° C. and weighed, the total loss thus found will represent:

The moisture = H.
The rosin = R.
The volatile hydrocarbons = T.

It is sufficient to determine two of these factors; the third could then be determined by difference. But as has been mentioned before, the ether extract can not be obtained in any degree

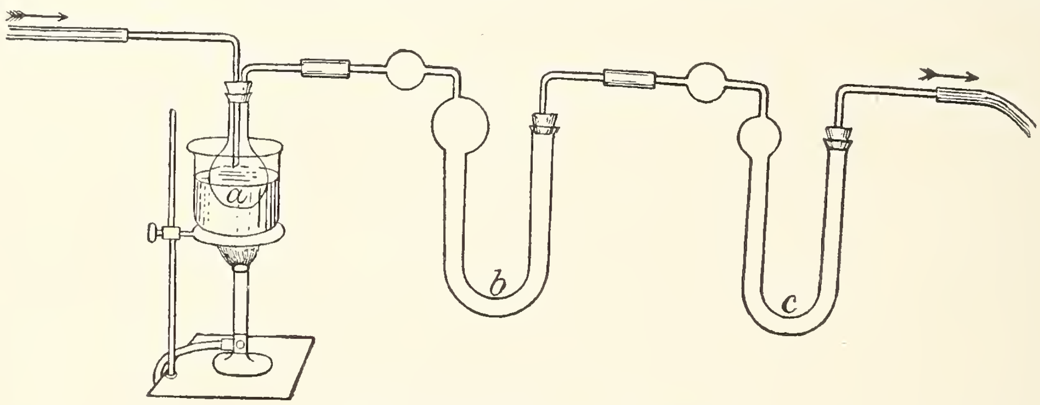


FIG. 85.—Method of chemical analysis of turpentine.

of purity without loss of turpentine. The evaporation of ether in a stream of dry air, as proposed by Dragendorf, for the estimation of essential oils in general, does not give satisfactory results with turpentine oil, as Dragendorf himself observed.

A weighed quantity of a mixture of rosin and oil, made up in about the same proportions as they exist in crude turpentine, was dissolved in a suitable amount of ether. The latter was then evaporated in a current of dry air till the odor of ether was hardly noticeable. The mixture was found to have gained considerably in weight by retaining ether in the thick sirupy oleorosin. It was only by heating at 100° C. for some time that all of the solvent could be driven off, and then the mixture was found to have lost in weight. Repeated trials proved that this method could not be used safely.

An attempt was then made to determine the quantities H and R, and thus find T by difference A weighed quantity of wood shavings was placed in a small flask a. The latter was connected on one side with a tray of drying bottles, on the other two $CaCl_2$ tubes b and c, similar in size and form. The flask is immersed in boiling water and a current of dry air is passed through the whole apparatus for one and one-half hours. The flask is then cooled and air is passed for one and one-half hours longer.

It was thought that while b would retain all the moisture and a portion of the volatile compounds, c would retain about the same amount of the volatile products only. Gain in weight of

c subtracted from that of b would then give the moisture H. The sample of wood shavings is then exhausted with ether, the latter evaporated, and the residue heated at about 140° to 150° to constant weight; this gives the rosin R. If L be the total loss by extraction with ether, we have

$$L-H+R=T.$$

But it was soon found by experiments upon pure turpentine oil that the two $CaCl_2$ tubes did not retain an equal amount of volatile oil. The quantity retained depended upon many circumstances, the chief one being the amount of moisture already present in the $CaCl_2$ tubes.

Even had the tubes retained quantities of turpentine oil, this method would still have the objection that one of the constituents was to be determined by difference—an objection especially serious when the ingredient to be so determined is small in comparison with the materials to be weighed.

The writer has therefore attempted to make use of a somewhat different principle. A few trials were sufficient to show that the method promised to give satisfactory results. The basis of the method is the same which served for the production of Russian turpentine oil on a large scale, namely, the distillation of the volatile products from the wood itself, without previously obtaining the turpentine. But instead of condensing the volatile products, their vapors are passed over heated copper oxide, whereby they are burned to water and carbon dioxide. Many trials were made with this method upon pure materials and on samples of resinous wood. As the results were found to be entirely concordant and satisfactory, the method was adopted, and by it were obtained the results presented in this report.

DESCRIPTION OF THE METHOD EMPLOYED.

A weighed amount of wood shavings is placed in a straight $CaCl_2$ tube a. The tube is connected on one side by means of a capillary tube with a drier A, which serves for freeing the air from moisture and CO_2. The other end of the tube is connected with an ordinary combustion

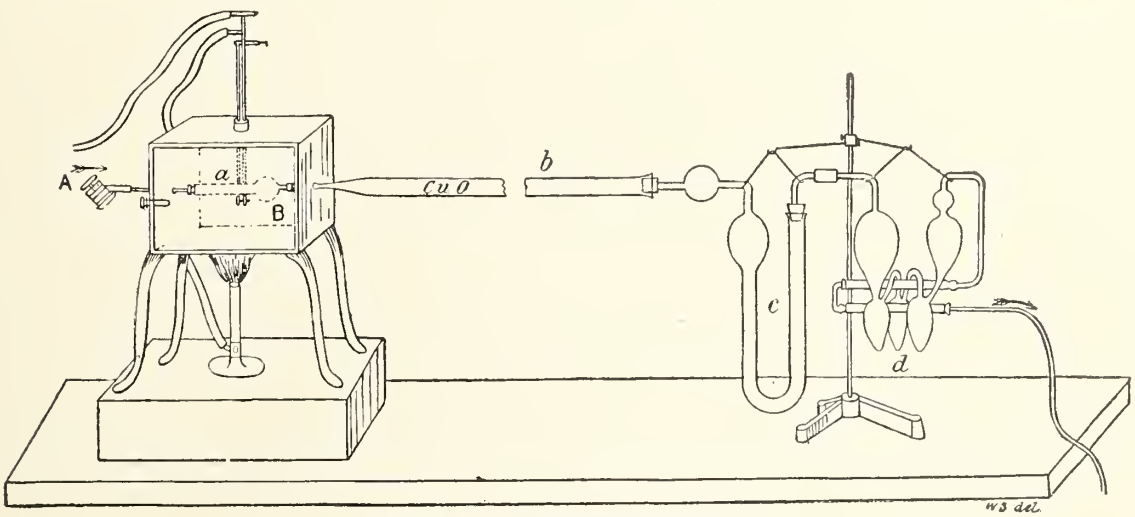


FIG. 86.—Method of distillation of turpentine.

tube b containing granulated CuO. The tube is drawn out at one end as is shown in the figure, and the narrow portion is loosely filled with asbestus wool. The connection is made glass to glass, so that the vapors of distillation do not come in contact with any rubber tubing. The forward end of the combustion tube is connected with a $CaCl_2$ tube c, one-half of which is filled with granulated $CaCl_2$ and the second half with P_2O_5. Then follows a potash bulb d provided with two straight tubes, the first one filled with solid KOH, the second with P_2O_5. The last tube is connected with an aspirator.

All the connections having been made air-tight, the connection between the tube a and the drier A is shut off by means of a clamp and the aspirator turned on. When the combustion tube has been heated to dull redness the burner under the air-bath B is lit and the temperature raised to 110°–120° C. The moisture contained in the tube escapes quite rapidly, carrying with it some turpentine oil. The capillary tube at the other end of A practically checks backward diffusion

or any accumulation of condensed vapors. In about fifteen minutes all the moisture appears at the forward end of the combustion tube. The clamp is now opened and a stream of air at the rate of somewhat over one liter an hour is passed through the whole apparatus, while the temperature of the air bath is raised to 155° to 160° C., and kept at that point for about forty-five minutes. Toward the end of the operation the temperature is raised to 165° to 170° C. for ten minutes. Then the light under the air bath is turned off and air aspirated for twenty to twenty-five minutes longer. As the air bath is in close contact with the combustion furnace, the whole length of the tube is kept at a temperature above the boiling point of turpentine oil. In this way a complete distillation is insured.

All the moisture is retained by *c*, while the CO_2 is absorbed in the potash bulb *d*. The gain of weight in *c* represents the moisture originally present in the sample of wood plus the water produced in the combustion of the hydrocarbons. The gain in weight of *d* represents the amount of CO_2, derived from the combustion of the volatile products.

The tube *a* is now transferred to an ordinary Soxhlet's extraction apparatus and exhausted with ether. The latter is distilled off, the residue dried for about two hours at 100° C., and weighed. This represents the amount of rosin in the sample of wood taken.

As has been previously mentioned, the volatile oil of the oleoresin is not pure australene, $C_{10}H_{16} = (C_5H_8)_2$. It probably contains some other hydrocarbons, either of the same formula or belonging to the class of polyterpenes $(C_5H_8)_n$. It is clear that whichever they be their percentage composition is alike in all; they all have C = 88.23 per cent, H = 11.77 per cent. Therefore, so far as the combustion of the volatile terpenes is concerned, they can all be represented by the equation:

$$\underbrace{C_{10}H_{16}}_{136} + 14 O = \underbrace{10\ CO_2}_{440}, = \underbrace{8\ H_2O}_{144}$$

In other words, 440 parts of CO_2 are derived from 136 parts of volatile terpenes.

$$440:136 = 1:X;\ X = 0.3091,$$

i. e., 1 part of CO_2 obtained in the combustion represents 0.309 parts of the volatile hydrocarbons.

For every 440 parts of CO_2 produced there are 144 parts of H_2O formed.

$$440:144 = 1:X;\ X = 0.3272,$$

i. e., simultaneously with 1 part of CO_2 there is produced 0.327 parts of H_2O.

Let the weight of the sample taken = W,

Let the weight of CO_2 obtained = W′,

Let the weight of H_2O obtained = W″,

Then—$W' \times 0.309 = T$, the amount of volatile hydrocarbons.

$W' \times 0.327 = H'$, the amount of H_2O corresponding to the volatile hydrocarbons.

$W'' \times - H', = H$ the amount of moisture in the wood.

$\frac{T}{W}$ = per cent of T; $\frac{H}{W}$ = per cent of moisture.

Thus the moisture, the volatile hydrocarbons, and rosin are obtained directly from the same sample. Where many estimations are to be made, it is of course unnecessary to cool down the combustion tube between successive combustions.

The temperature of distillation.—Some experiments were made to determine at what temperature it is safe to conduct the distillation. Although pure turpentine boils at 156–160° C., yet in open air it can be volatilized at a much lower temperature, even on the water bath, without any difficulty. Especially is this the case when the vapors are removed as soon as formed by a stream of air, but it must be remembered that the volatilization of the essential oil directly from the wood might be considerably hindered by the large amount of rosin.

A sample of wood distilled by the method outlined above gave the following results at different temperatures:

	120°	140°	150°	160°	170°
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
T =	1.09	1.18	1.30	1.26	1.32
H_2O =	11.17	11.33	11.23	....	....

Another sample gave:

	160°	180°
	Per cent.	*Per cent.*
$T=$	4.00	3.98
$H_2O=$	8.79	....

The results would indicate that the distillation is practically complete at 160°, and that the wood itself does not contribute any CO, by partial decomposion at that high temperature; for, should the latter be the case, higher results might be expected at 180° than at 160°, and then the sapwood would give much higher numbers for turpentine oil than those actually obtained.

Even if this method does not give the absolute amounts of volatile hydrocarbons, yet it certainly gives results very near the truth, and, what is more important, under the same conditions it gives constant results. Therefore, by employing strictly parallel conditions in the analysis of the different samples, results are obtained which can be safely used as indices of comparison of the relative amounts of volatile hydrocarbons in the samples under analysis.

MATERIAL FOR ANALYSIS AND METHOD OF DESIGNATION.

Materials.—Trees No. 52 and 53, abandoned five years.
Trees No. 60 and 61, abandoned one year.
Trees No. 1 and 2, not tapped.
Trees 54–57, abandoned five years.
Trees 58–59, abandoned five years.
Trees 63–65, abandoned one year.
Trees 66–69, abandoned one year.
Trees 17–19, not tapped.
Generally Disk II is 23 feet from ground.
Disk III is 33 feet from ground.
Disk IV is 43 feet from ground.

Method of designation.—It was thought best to make a somewhat detailed analysis of a few bled and unbled trees in order to gain an insight into the quantitative distribution of turpentine in the trees. Each disk was divided into pieces of about thirty rings each, the heart and sapwood being kept separate. The number of the disk is designated by a roman figure, the kind of wood by either *s* for sapwood or *h* for heartwood. The arabic figure which precedes the *h* or *s* designates the number of the piece, counting for the sapwood from the bark; for the heartwood, from the line of division between sap and heart.

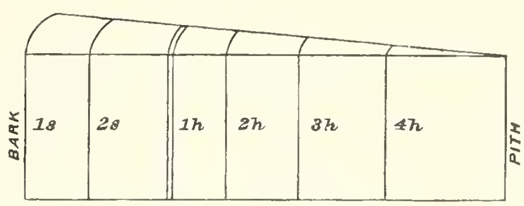


FIG. 87.—Distribution of turpentine in trees. (A piece marked 52 III 2*h* means tree No. 52, disk III, the second piece of the heart.)

Preparation of material.—The first six tables give the results of what might be called "detail" analysis, where each piece of about thirty rings has been analyzed separately. The material for analysis was prepared in the following way: A radial section of the disk, about 1 to 2 inches thick, is selected. A piece of 1 inch is cut off transversely, and the strip is then divided into pieces of about thirty rings each. From the freshly cut transverse surface about 15 grams of thin shavings are planed off and placed in a stoppered bottle. The exact amount used for analysis, usually from 3 to 5 grams, is found by weighing the bottle before and after taking out the portion for analysis.

The second set of tables, VII to XII, inclusive, give the results of "average" analysis. The material for these analyses was obtained by mixing equal quantities of shavings from the corresponding portions of several trees and taking for analysis an average sample of the mixture. The sapwood furnish one analysis and the heart wood was either analyzed as a whole or divided into portions, 1*h* and 2*h*, if of considerable thickness.

NOTES ON TABLES I TO XII.

Each table contains a column "calculated for wood free from moisture," giving the per cent of volatile hydrocarbons and rosin obtained by calculation from results actually found. Objections might be raised to this mode of interpreting the results. It might be said that the moisture in the wood can not be disregarded, because it is as much an essential proximate constituent of wood as the turpentine itself is. But since the analyses were not made soon after the trees had been felled, the moisture found in the samples does not represent the original moisture, nor

does it represent equal portions of it in all samples. The numbers given in the column "water" are of course suggestive as to the comparative degree of retention of moisture by the different samples, since the latter were all exposed to about the same influences. But it seemed best to compare the amounts of volatile hydrocarbons and rosin on wood free from that variable constituent; the more so as some time elapsed between the analysis of the first and last samples.

The last column in each table contains the ratio between the volatile hydrocarbons and rosin. This ratio is multiplied by 100, and means that for every 100 parts of rosin as many parts of the volatile hydrocarbons are found as is indicated in the column. This ratio $\left(\frac{T}{R}\right)$ is of little value in cases when the amount of turpentine is small, because a very small increase of the first constituent—an increase within experimental error—will change the quotient considerably. An increase of 0.07 per cent of volatile hydrocarbons in 60, IV, 1s will bring up $\frac{T}{R}$ from 7.2 to 10. A decrease of 0.07 per cent in 52, IV, 2s will change $\frac{T}{R}$ from 25.20 to about 19. These numbers are therefore of very little significance when applied to the sapwood of all samples, to entire tree 52, and to some parts of trees 60 and 1, all of which show only small portions of turpentine.

DISCUSSION OF RESULTS OBTAINED.

Relation of rosin and volatile hydrocarbon to moisture.—The amount of moisture retained by different samples does not seem to have any direct relation to the amount of oleoresin in these samples. Yet in the same tree, or rather in the different parts of the same disk, there seems to exist something like a relation of the two. This is especially noticeable in tree No. 53. The moisture retained seems to vary inversely with the amount of oleoresin in the sample. Compare, for example, in 53 II, 1*h*, 2*h*, 3*h*; in 53 III, 1*h*, 2*h*, 3*h*, 4*h*; in 53 IV, 2*h*, 3*h*, 4*h*. The piece richest in oleoresin is generally the poorest in moisture. But this is by no means a universal rule. Some trees show about the same per cent of moisture in parts widely differing from each other in the amounts of turpentine, and in many instances a smaller amount of turpentine is associated with a smaller per cent of moisture.

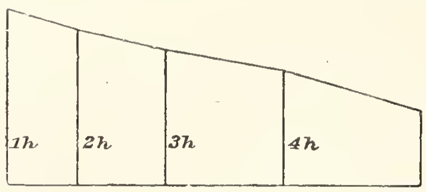


FIG. 88.—Relationship of different parts of same disk.

Sapwood and heartwood.—All the analyses, detail and average, show conclusively that the sapwood is comparatively very poor in turpentine; it is immaterial whether it comes from a rich tree or a poor one, from a tapped tree or an untapped one. The turpentine in sapwood reaches 3 to 4 per cent in very rich trees, as in Nos. 53, 61, and 2; in the remaining trees it is 2 to 3 per cent. Consequently the results obtained for sapwood are not taken into account in the following paragraphs. When differences between trees are spoken of, it applies entirely to heartwood.

The different parts of the same disk show a constant relation in nearly all instances. In most cases 1*h* is the richest, and the heartwood grows poorer as we approach the pith of the tree. In a few cases, as in 1 III and in 1 IV, 1*h* and 2*h* are practically identical, while in some instances, in 2 III, 61 II, 61 III, and 53 II, 1*h* is poorer than 2*h*. In nearly all cases the decline is marked in 3*h*, and 4*h* is usually found to be the poorest part of the disk. This relationship can be represented in a general way by the following curve:

Relation of volatile hydrocarbons to rosin.—As the turpentine in the tree is a solution of rosin in an essential oil, it will follow that the richer a tree is in turpentine the richer it will be in the constituents that go to make up this mixture. One would also expect that the ratio between the volatile hydrocarbons and rosin would be tolerably constant in the different parts of the same tree, but the results of analysis do not indicate it. They show that this ratio increases with the amount of rosin. A part of heartwood having twice as much rosin as another part will contain more than twice as much volatile products as the second part. This is true in a general sense of parts of the same disk, of parts of different disks in the same tree, and parts from different trees. There is no distinction in that respect between bled and unbled trees. This relationship can be formulated in the following way: The crude turpentine from heartwood rich in oleoresin will yield a comparatively larger amount of turpentine oil than the turpentine from heartwood poor in oleoresin.

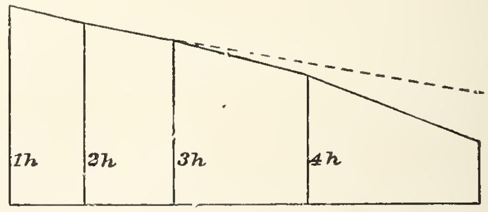


FIG. 89.—Yield of volatile oil from constant quantity of turpentine.

It has been shown that the heartwood grows poorer from $1h$ toward the pith of the tree. It will therefore follow from what has been said in the preceding paragraph that $\frac{T}{R}$ will also grow smaller from $1h$ to the pith. The yield of volatile oil from a constant quantity of turpentine can be expressed in a general way by a graphic illustration similar to that which expresses the yield of total oleoresin from different parts of the disk.

It is difficult to explain satisfactorily this decrease of $\frac{T}{R}$. The two parts of the radial sections that have been the longest exposed to air are $1s$ and the last h. The question naturally arises, May not the decrease of $\frac{T}{R}$ be due to a greater evaporation of volatile hydrocarbons from these two ends? But this can hardly be so. No. 53, II, $4h$ was analyzed at intervals of two months and furnished the following data:

	I, Sept. 28.	II, Nov. 27.
H_2O	=11.23	7.24
T	= 1.30	1.34
R	= 7.96	8.12

Calculated for wood free from moisture:

	I.	II.
T	=1.30	1.30
R	=8.96	8.75

Sufficient experimental data are lacking to prove conclusively that the volatile hydrocarbons do not evaporate to any extent from the heartwood except from freshly cut surfaces of it.

Relation between different disks of the same tree.—There is no constant relation between the different disks of the same tree so far as the amount of oleoresin is concerned. Although the disks do vary from each other, the variation can not be connected with gravitation, by virtue of which the lower disks would contain a larger amount of turpentine than the upper ones; for different trees vary from each other considerably in this respect, the variation being apparent in both bled and unbled trees. If a, b, c stand for the amounts of oleoresin in disks denoted by Roman numerals, the relative magnitudes being represented by the letters in the alphabetic order, then the results of analysis can be condensed in the following table for the trees denoted in Arabic numbers:

	53.	60.	61.	1.	2.
IV.....	*a*	*b*	......	*a*	*c*
III....	*b*	*c*	*a*	*c*	*b*
II.....	*c*	*a*	*b*	*b*	*a*

It is evident that no constant relation as to amounts of oleoresin exists between the disks of the same tree.

Comparison of tree 52 with 53.—These two trees were both supposed to have been sound, healthy trees at the time of felling, and yet they differ from each other as much as two trees could differ. The heartwood of one is very rich in turpentine; that of the other contains comparatively very small quantities—only a trace. How to explain the difference? Previous to felling they had both been tapped for four consecutive years; consequently both must have contained considerable amounts of turpentine. Since the last tapping they stood for five years side by side, both exposed to the same influences. This great difference can not be traced directly to tapping, for the latter, it may be assumed, would have affected both trees equally. The cause of the difference between 53 and 52 ought to be looked for, rather, in the condition of the two trees before tapping. In connection with this it would be interesting to know how much turpentine each tree had yielded when tapped.

Comparison of trees 60 and 61.—There is a decided difference between the two trees. The highest numbers in 60 are 0.84 per cent for volatile hydrocarbons and 5.35 for rosin, while in 61 0.75

and 5.67 are the lowest numbers for the corresponding constituents, the highest being 3.49 and 16.29, respectively. Here again we have two trees of about the same age, under apparently the same conditions of growth, tapped at the same time and abandoned for the same length of time before felling, and yet differing very widely from each other. It is difficult to conceive why tapping should have affected the heartwood of these two trees in such a strikingly different manner. If the assumption is made that the tapping had drained both trees equally, what explanation can be given for the fact that within one year of abandonment one tree is very rich in turpentine while the other has less than one-fourth as much?

Comparison of trees 52 and 53 with 60 and 61.—Compare 53 and 61. Here we have two trees both very rich in turpentine, but while 53 had five years of rest after tapping, 61 had only one year. Had the tapping forced the trees to pour out their oleoresin previously stored up in the heart, we should expect to find in the time of rest the prime factor for the tree in resuming its natural condition; but, on the contrary, results of analysis show that time of abandonment before felling is of little importance. While we can have a tree very rich in turpentine within five years after tapping, we can also have trees rich and poor even within one year, and trees almost totally deprived of turpentine in the heartwood within five years after tapping.

Comparison of 1 with 2.—These two trees had never been tapped, and yet neither is rich in turpentine. No. 2 contains about twice as much turpentine as No. 1, the difference becoming smaller as we go up the tree. The highest numbers for 2 are 1.93 and 14.19 for T and R, respectively, the lowest 0.86 and 5.89, with an average of about 1 and 7. We can say that there is as much difference between untapped trees as there is between trees that have been tapped.

Average analyses.—The average analyses cover 16 trees. Thirteen trees furnish four sets of analyses of tapped trees and 3 trees furnish one set of untapped. The results obtained are summarized in the following table:

Tree No.	II.			III.			Remarks.
	T.	*R.*	$\frac{T}{R} \times 100.$	*T.*	*R.*	$\frac{T}{R} \times 100.$	
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*		
54-57	0.93	5.88	15.58	0.58	3.98	14.04	Abandoned 5 years.
57-59	.80	4.06	19.63	.82	4.29	19.10	Do.
63-65	.91	5.32	17.18	....	....	....	Abandoned 1 year.
66-69	.89	4.95	18	....	....	....	Do.
17-19	.64	2.98	21.37	.71	3.21	21.76	Not tapped.

These results show a pretty constant average number for turpentine in tapped trees. The heartwood of untapped trees is poorer in both volatile oil and rosin than that of tapped trees. And here again it is worthy of notice that time of abandonment is of little importance to tapped trees. The trees that had been abandoned for one year are fully as rich as those that had five years to recover from tapping.

Comparison of tapped with untapped trees.—If now the heartwood of tapped trees be compared with that of untapped, one is at a loss as to what conclusions should be drawn from so few analytical data. It is remarkable that the two richest trees and the poorest tree are among those that had been tapped. Of the remaining 19 trees, there is no difference between the 14 tapped and 5 untapped. Whatever differences are found among bled trees are equally found among those that have not been tapped.

Indeed, from the study of the results of analyses the writer is of the opinion that the difference in untapped trees is due to the same cause as the difference in trees that have been tapped. As stated above, the cause of the difference among tapped trees can not be traced directly to tapping; it ought to be looked for, rather, in the condition of the trees previous to tapping.

The difference between trees 52 and 53 can be explained on the following hypothesis: 53 had been a rich tree from early growth and had a large amount of turpentine stored up in the heartwood; 52 for some reason or other had very little stored away. When the two trees were subjected to tapping they gave up whatever turpentine they had in the sapwood and whatever they could produce from season to season, till at the end of four years the production became too small in amount and too poor in quality. The trees were then abandoned. But tree No. 53 had its oleoresin in the heartwood untouched, while No. 52 had hardly any before tapping, and for the same unknown cause did not store away any in the heartwood after the tree had been abandoned.

The explanation offered in the preceding paragraph gains still more probability when trees 60 and 61 are compared with each other and also with 52 and 53. The difference between 1 and 2, the results of average analyses—all these are very suggestive of the theory that the sap, and not the heart of the tree, supplies the turpentine when the tree is tapped. The fact that the heartwood of trees felled one year after tapping is fully as rich or as poor as that of trees felled five years after tapping, seems to the writer of especial significance, for it shows that the richness of the heartwood in a tapped tree is independent of time of rest before felling.

It is a well-known fact that when a pine tree is cut transversely, liquid turpentine immediately appears on the fresh surface of the sapwood, while the heartwood remains perfectly clear. It would seem as if the turpentine in the sap is far less viscid than that in the heart of a tree. It is probable that the turpentine in the sap is richer in volatile hydrocarbons than that in the heart. (A difference of cell structure and manner of existence of oleoresins may also account for this difference in part.—B. E. F.)

It is generally stated that crude turpentine as obtained on a large scale yields from 10 to 25 per cent of volatile oil. This gives $\frac{T}{R}=11.11$ to 30, with an average of over 20. This average is somewhat higher than that for the $\frac{T}{R}$ as found for the turpentine from heartwood of the 21 trees analyzed. Although experimental data are wanting to show conclusively that the difference in the consistency of the oleoresin from sapwood and heartwood is due to a difference in the relative amount of volatile oil, yet it is quite probable that this should be the cause. The oleoresin in the heartwood of trees has been produced for the most part when the heartwood was yet sapwood. Therefore that part of turpentine which is found in the heartwood is the oldest in age and consequently has been exposed the longest to oxidizing influences of air, which gradually replace the water when the sapwood changes to heartwood. It is the same kind of oxidation and of thickening which takes place when crude turpentine is exposed to the air and sun, or when a fresh cut is made in the bark of a tree. It is probably for the same reason that $\frac{T}{R}$ becomes smaller as we approach the pith of the tree, because the parts nearest the pith are the oldest.

It is difficult to conceive how the thick oleoresin of the heartwood could be made to flow toward the incision when a tree is tapped. It is also difficult to explain by what means the tree could change this thick turpentine into a less viscid solution in order that it may flow toward the wound.

One would judge, a priori, from the great difference in the consistency of the turpentine in the heart and sap that only the liquid turpentine will flow when a tree is tapped. Tapping will then have little effect, if any, upon the oleoresin stored up in the heartwood of the tree. A tree whose heartwood is rich in turpentine will remain so after tapping.

The writer is not willing to generalize too hastily from so few results and consider them as a solution of the problem. A large number of analyses, devoid of the possibility of chance selection of samples, is necessary before a positive or a negative answer can be given to the question, does the tapping of trees for turpentine affect the subsequent chemical composition of the heartwood?

But, however few in number the results are, they admit of the following conclusions:

(1) Trees that have been tapped can still contain very much turpentine in the heartwood.

(2) Trees that have been abandoned for only one year before felling can contain fully as much turpentine in the heartwood as trees that have been abandoned for five years.

(3) Trees that have not been tapped at all do not necessarily contain more turpentine in the heartwood than trees that have been tapped.

The following diagram serves to show what proportion of each disk was involved in each of the detail analyses, and the results in each case. The right-hand vertical line represents the pith of the tree, the horizontal lines represent the radical extension of each disk, as numbered by roman number, the position of the disk in the tree being maintained as in nature, IV being the top, II the lower, and III the intervening disk. The subdivisions of radii represent the actual divisions of the disk to scale of one-half natural size, the portions to the left of the heavy subdivision line representing sapwood *s* 1 and *s* 2; the portions to the right heartwood *h*, *h*, divided according to the method as indicated above. The four columns of figures over each disk piece represent results pertaining to that piece; they stand in order from the top for (1) number of rings, (2) volatile

hydrocarbons, (3) rosin, (4) ratio $\frac{T}{R}$; (2) and (3) as calculated on wood free from moisture. For instance, for tree No. 53, disk IV, s2, we find—

$$40 = \text{Number of rings.}$$
$$0.40 = \text{Per cent of volatile hydrocarbons.}$$
$$3.81 = \text{Per cent of rosin.}$$
$$10.37 = \frac{T}{R}.$$

Tree No. 53.

IV.	40. 0.40 3.81 10.37	30. 0.46 3.96 11.60	34. 4.56 24.01 19.02	33. 4.49 22.23 20.12	31. 3.86 17.74 21.77	35. 2.66 15.19 17.53	
III.	40. 0.39 2.96 13.01	37. 0.42 3.02 13.82	35. 3.87 21.77 17.85	38. 3.81 20.09 18.94	30. 2.10 11.97 17.53	18. 1.25 9.71 13.10	
II.	37. 0.18 0.97 18.39	40. 0.19 0.96 19.77	33. 2.56 12.02 21.23	32. 4.39 24.70 22.43	32. 2.22 12.30 18.29	28. 1.46 8.96 16.33	

Tree No. 52.

IV.	40. 0.26 1.40 18.78	35. 0.34 1.34 25.20	32. 0.15 1.65 9.33	34. 0.22 1.97 11.11	30. 0.23 1.72 13.38	30. 0.26 1.92 13.64	
III.	30. 0.25 1.99 12.71	40. 0.25 1.87 13.67	30. 0.15 1.77 8.64	30. 0.20 1.87 10.51	32. 0.14 1.86 7.65	27. 0.18 1.60 9.65	11. 0.18 1.53 9.26
II.	40. 0.30 2.19 13.64	40. 0.31 2.01 15.48	36. 0.30 2.17 14.14	32. 0.26 1.83 14.38	35. 0.17 1.98 8.83	24. 0.17 1.51 11.60	

Tree No. 61.

III.	30. 0.22 3.01 7.35	36. 0.28 2.75 10.20	40. 3.07 13.55 22.65	33. 3.49 16.29 21.42	35. 3.14 14.18 21.42	30. 1.08 8.04 13.39
II.	35. 0.20 3.01 6.50	35. 0.26 3.11 8.36	36. 1.57 7.88 19.85	33. 2.69 13.57 19.86	30. 2.92 11.34 25.81	35. 0.75 5.67 13.28

Tree No. 60.

IV.	30. 0.16 2.32 7.02	27. 0.24 2.66 9.09	28. 0.84 5.35 15.59	36. 0.41 3.13 12.85	40.	
III.	30. 0.28 2.65 10.33	34. 0.35 2.88 12.16	30. 0.58 3.60 15.27	36. 0.40 2.99 13.23	36. 0.42 2.42 17.04	20. 0.50 3.39 14.70
II.	30. 0.29 2.26 12.74	35. 0.33 2.63 12.56	37. 0.71 5.03 14.07	33. 0.51 2.71 18.62	35. 0.73 5.19 14.03	27. 0.47 3.62 13.00

Tree No. 1.

IV.	30. 0.22 1.43 15.27	28. 0.25 1.57 15.97	32. 1.07 7.61 14.12	19. 1.06 6.62 16.04	
III.	30. 0.32 2.25 14.49	33. 0.34 2.25 13.90	30. 0.94 4.90 19.11	25. 0.73 5.12 14.21	13. 0.40 3.57 11.20
II.	30. 0.20 1.06 18.55	35 0.17 1.32 13.72	35. 0.18 6.57 17.97	34. 0.66 3.92 16.67	15. 0.37 2.23 16.50

Tree No. 2.

IV.	30. 0.31 2.52 12.12	36. 0.34 2.71 12.36	30. 1.13 8.10 13.98	30. 0.87 6.41 13.53		
III.	30. 0.18 1.95 8.94	36. 0.24 2.24 10.06	33. 1.37 9.14 14.77	28. 0.92 5.89 15.61	17. 0.86 7.40 11.64	
II.	30. 0.20 4.29 4.56	26. 0.31 3.05 10.00	34. 1.55 10.10 15.35	30. 1.93 14.19 14.4	30. 1.39 8.78 15.75	11. 1.16 8.94 12.99

FIG. 90.—Diagram of detail analyses, representing radial dimensions of test pieces in each disk. Scale, one-half natural size.

TABLE I.—TREE No. 53.

No. of disk.	Part of disk.	Number of rings.	Width.	Water.	Volatile hydrocarbon.	Rosin.	Calculated on wood free from moisture. Volatile hydrocarbon.	Calculated on wood free from moisture. Rosin.	$\frac{\text{Vol. hydroc.}}{\text{Rosin.}} \cdot 100$
			Cm.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent*	*Per cent.*	
II	1*s*	37	3.3	10.51	0.16	0.87	0.18	0.97	18.39
	2*s*	40	4.0	10.05	0.17	0.86	0.19	0.96	19.77
	1*h*	33	3.0	9.11	2.32	10.93	2.56	12.02	21.23
	2*h*	32	2.9	8.79	4.00	17.83	4.39	24.70	22.43
	3*h*	32	5.0	8.47	2.03	11.26	2.22	12.30	18.29
	4*h*	28	10.0	*11.23	1.30	7.96	1.46	8.96	16.33
III	1*s*	40	2.7	9.08	0.35	2.69	0.39	2.96	13.01
	2*s*	37	2.6	8.90	0.38	2.75	0.42	3.02	13.82
	1*h*	35	3.5	7.89	3.57	20.05	3.87	21.77	17.85
	2*h*	38	4.1	8.04	3.50	18.48	3.81	20.09	18.94
	3*h*	30	5.5	8.55	1.92	10.95	2.10	11.97	17.53
	4*h*	18	7.0	8.79	1.14	8.86	1.25	9.71	13.10
IV	1*s*	40	4.0	8.96	0.36	3.47	0.40	3.81	10.37
	2*s*	30	3.0	8.67	0.42	3.62	0.46	3.96	11.60
	1*h*	34	3.9	8.04	4.20	22.08	4.56	24.01	19.02
	2*h*	33	3.0	7.93	4.13	20.56	4.49	22.33	20.12
	3*h*	31	5.8	8.65	3.53	16.21	3.86	17.74	21.77
	4*h*	15	5.3	9.55	2.41	13.74	2.66	15.19	17.53

*53, II, 4*h* has been analyzed some three weeks earlier than the remaining parts of this tree, hence a large per cent of moisture.

TABLE II.—TREE No. 52.

II	1*s*	40	3.1	9.72	0.27	1.98	0.30	2.19	13.64
	2*s*	40	3.9	9.77	0.28	1.81	0.31	2.01	15.47
	1*h*	36	4.6	8.67	0.28	1.98	0.30	2.17	14.14
	2*h*	32	3.0	8.44	0.24	1.68	0.26	1.83	14.38
	3*h*	35	6.8	8.80	0.16	1.81	0.17	1.98	8.83
	4*h*	24	7.4	8.55	0.16	1.38	0.17	1.51	11.60
III	1*s*	30	3.0	9.12	0.23	1.81	0.25	1.99	12.71
	2*s*	40	3.5	9.00	0.23	1.68	0.25	1.87	13.67
	1*h*	30	3.4	8.44	0.14	1.62	0.15	1.77	8.64
	2*h*	30	3.0	8.51	0.18	1.71	0.20	1.89	10.51
	3*h*	32	4.8	8.37	0.13	1.70	0.14	1.86	7.65
	4*h*	27	6.9	9.35	0.14	1.45	0.15	1.60	9.65
	5*h*	11	5.0	9.21	0.13	1.39	0.14	1.53	9.26
IV	1*s*	40	3.5	8.88	0.24	1.28	0.26	1.40	18.78
	2*s*	35	3.3	8.49	0.31	1.23	0.34	1.34	25.20
	1*h*	32	3.0	9.08	0.14	1.50	0.15	1.65	9.33
	2*h*	34	2.8	8.86	0.20	1.80	0.22	1.97	11.11
	3*h*	30	3.6	8.48	0.21	1.57	0.23	1.72	13.38
	4*h*	30	6.8	8.10	0.24	1.76	0.26	1.92	13.64

TABLE III.—TREE No. 61.

II	1*s*	35	3.0	7.94	0.18	2.77	0.20	3.01	6.50
	2*s*	35	3.0	7.90	0.24	2.87	0.26	3.11	8.36
	1*h*	36	2.8	7.35	1.45	7.30	1.57	7.88	19.85
	2*h*	33	3.2	7.58	2.49	12.54	2.69	13.57	19.86
	3*h*	30	4.5	7.64	2.70	10.46	2.92	11.34	25.81
	4*h*	35	9.5	7.10	0.70	5.27	0.75	5.67	13.28
III	1*s*	30	3.0	7.65	0.20	2.78	0.22	3.01	7.35
	2*s*	36	2.7	7.43	0.26	2.55	0.28	2.75	10.20
	1*h*	40	3.1	7.14	2.85	12.58	3.07	13.55	22.65
	2*h*	33	3.2	7.46	3.23	15.08	3.49	16.29	21.42
	3*h*	35	6.0	7.41	2.91	13.59	3.14	14.18	21.42
	4*h*	30	8.0	7.09	1.00	7.47	1.08	8.04	13.39

TABLE IV.—TREE No. 60.

II	1*s*	30	2.7	9.91	0.26	2.04	0.29	2.26	12.74
	2*s*	35	2.8	9.34	0.30	2.39	0.33	2.63	12.56
	1*h*	37	3.5	8.72	0.65	4.62	0.71	5.03	14.07
	2*h*	33	4.5	9.15	0.46	2.47	0.51	2.71	18.62
	3*h*	35	4.6	8.01	0.67	4.71	0.73	5.19	14.02
	4*h*	27	6.5	8.45	0.43	3.31	0.47	3.62	13.00
III	1*s*	30	3.1	8.74	0.25	2.42	0.28	2.65	10.33
	2*s*	34	2.8	8.60	0.32	2.63	0.35	2.88	12.16
	1*h*	30	3.2	8.68	0.53	3.47	0.58	3.80	15.27
	2*h*	36	4.4	9.02	0.36	2.72	0.40	2.99	13.23
	3*h*	36	4.5	7.73	0.38	2.23	0.42	2.42	17.04
	4*h*	20	6.0	7.73	0.46	3.13	0.50	3.39	14.70
IV	1*s*	30	2.6	7.51	0.15	2.15	0.16	2.32	7.02
	2*s*	27	2.6	7.84	0.22	2.45	0.24	2.66	9.09
	1*h*	28	3.7	7.77	0.77	4.94	0.84	5.35	15.59
	2*h*	36	5.0	8.12	0.37	2.88	0.41	3.13	12.85
	3*h*	40	8.0	7.92	0.26	2.81	0.28	3.05	9.18

TABLE V.—TREE No. 1.

No. of disk.	Part of disk.	Number of rings.	Width.	Water.	Volatile hydrocarbon.	Rosin.	Calculated on wood free from moisture. Volatile hydrocarbon.	Calculated on wood free from moisture. Rosin.	$\frac{\text{Vol. hydroc.}}{\text{Rosin.}} \times 100$
			Cm.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
II	1*s*	30	2.0	8.67	0.18	0.97	0.20	1.06	18.55
	2*s*	35	3.0	8.77	0.16	1.21	0.17	1.32	13.72
	1*h*	35	3.6	8.56	1.08	6.01	1.18	6.57	17.97
	2*h*	34	6.5	8.39	0.60	3.60	0.66	3.92	16.67
	3*h*	14	3.0	7.67	0.34	2.06	0.37	2.23	16.50
III	1*s*	30	2.8	7.94	0.30	2.07	0.32	2.25	14.49
	2*s*	33	3.0	7.92	0.31	2.23	0.34	2.42	13.90
	1*h*	30	3.8	8.13	0.86	4.50	0.94	4.90	19.11
	2*h*	25	4.2	7.78	0.67	4.72	0.73	5.12	14.21
	3*h*	13	3.5	7.57	0.37	3.30	0.40	3.57	11.22
IV	1*s*	30	2.2	8.33	0.20	1.31	0.22	1.43	15.27
	2*s*	28	2.8	8.12	0.23	1.44	0.25	1.57	15.97
	1*h*	32	5.0	7.94	0.99	7.01	1.07	7.61	14.12
	2*h*	19	5.2	7.73	0.98	6.11	1.06	6.62	16.04

TABLE VI.—TREE No. 2.

II	1*s*	30	3.0	7.65	0.18	3.95	0.20	4.29	4.56
	2*s*	26	2.7	8.19	0.28	2.80	0.31	3.05	10.00
	1*h*	34	3.5	7.31	1.44	9.25	1.55	10.10	15.35
	2*h*	30	5.0	8.11	1.77	13.05	1.93	14.19	14.41
	3*h*	30	6.0	8.16	1.27	8.06	1.39	8.78	15.75
	4*h*	11	4.2	7.88	1.07	8.24	1.16	8.94	12.99
III	1*s*	30	2.7	8.00	0.16	1.79	0.18	1.95	8.94
	2*s*	36	3.0	8.01	0.22	2.06	0.24	2.24	10.06
	1*h*	33	3.2	7.44	1.25	8.46	1.37	9.14	14.77
	2*h*	28	5.5	7.78	0.85	5.44	0.92	5.89	15.61
	3*h*	17	4.8	7.12	0.80	6.87	0.86	7.40	11.64
IV	1*s*	30	2.7	8.20	0.28	2.31	0.31	2.52	12.12
	2*s*	36	3.0	8.08	0.31	2.49	0.34	2.71	12.36
	1*h*	30	3.6	8.10	1.04	7.44	1.13	8.10	13.98
	2*h*	30	7.6	7.81	0.80	5.91	0.87	6.41	13.53

TABLE VII—SUMMARY OF RESULTS OF TREES NOS. 54 TO 69 AND NOS. 17 TO 19.

Serial number of trees.	Part of disk.	Disk II. Volatile hydrocarbons.	Disk II. Rosin.	Disk II. $\frac{\text{Vol. hydr.}}{\text{Rosin.}} \times 100$	Disk III. Volatile hydrocarbons.	Disk III. Rosin.	Disk III. $\frac{\text{Vol. hydr.}}{\text{Rosin.}} \times 100$
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*	
54, 55, 56, 57	*s*	0.18	1.48	13.14	0.26	1.93	13.33
	1*h*	1.16	6.78	17.14	0.81	4.80	16.82
	2*h*	0.70	4.97	14.01	0.34	2.97	11.27
	h	0.93	5.88	15.58	0.58	3.89	14.04
58, 59	s	0.28	1.76	15.76	0.20	1.35	14.14
	h	0.80	4.06	19.63	0.82	4.29	19.10
63, 64, 65	*s*	0.18	1.74	70.00			
	1*h*	0.81	4.35	18.55			
	2*h*	1.00	6.29	15.80			
	h	0.91	5.32	17.18			
66, 67, 68, 69	s	0.14	1.78	8.00			
	h	0.89	4.95	18.00			
17, 18, 19	*s*	0.14	1.49	9.56	0.11	1.34	8.20
	1*h*	0.78	3.48	22.87	0.91	3.63	25.15
	2*h*	0.50	2.47	19.82	0.50	2.79	18.36
	h	0.64	2.98	21.37	0.71	3.21	21.76

TIMBER PHYSICS WORK.

The timber physics work was continued actively and the investigation extended to other kinds of timber, both conifers and hard woods. In 1896 the Division was in position to announce its findings with regard to the mechanical, physical, and structural study of the four principal Southern pines (Circular 12). Based, as these results are, on over 20,000 mechanical tests and over 50,000 weighings and measurements, they may fairly be regarded as final, and thus avoid future discussion and much fruitless and expensive private testing. According to this exhaustive study, the Cuban and long-leaf pine rank foremost among our timber pines, and are fully 20 to 25 per cent stronger than had previously been assumed. It also appeared that the wood of these species varies in strength directly as the weight (little discrepancies being well accounted for by variations in resin contents, which add only to weight and not to strength); that in the same tree the wood varies according to certain definite laws, being heaviest at butt, lightest in top, heavier in the interior, and lighter and weaker in the outer parts of saw-size timber; that thus the age when formed, as well as the position in the tree, exercises a definite influence which is generally far greater than the much-quoted influences of soil, locality, etc. In this latter respect it was clear

from the results that the oft-claimed superiority of the timber of certain localities is not substantiated by experiment, but that there is heavy and strong as well as lighter and weaker timber in every locality throughout the range of these species. The all-important effect of moisture was carefully considered throughout the work, and it was established that in general an increase in strength of at least 50 to 75 per cent takes place during ordinary seasoning, so that for all designing of covered work, as in ordinary architecture, this improvement may be depended upon and considered in the proportioning of the timbers.

The manner in which the valuable information was secured and communicated will appear from the following reprint of Circulars 12 and 15, issued in 1896 and 1897:

Southern Pine—Mechanical and Physical Properties.

THE MATERIAL UNDER CONSIDERATION.

The importance of reliable information regarding the pines of the South is evident from the fact that they furnish the bulk of the hard-pine material used for constructive purposes with an annual cut hardly short of 7,000,000,000 feet B. M., which, with the decline of the soft-pine supplies in the North, is bound to increase rapidly.

Although covering the largest area of coniferous growth in the country (about 230,000 square miles), proper economies in their use are nevertheless most needful, since much of this area is already severely culled and the cut per acre has never been very large. Hence the demonstration (a result of the investigations in this Division) that bled pine is as strong and useful as unbled, and the assurance that long-leaf pine is in the average 25 per cent stronger than it is often supposed to be, and therefore can be used in smaller sizes than customary at present, must be welcome as permitting a saving in forest resources which may readily be estimated at from eight to ten million dollars annually, due to this information.

The pines under consideration, often but imperfectly distinguished by consumers in name of substance, are:

(1) The long-leaf pine (*Pinus palustris*), also known as Georgia or yellow pine, and in England as "pitch pine," and by a number of other names, is to be found in a belt of 100 to 150 miles in width along the Atlantic and Gulf coasts from North Carolina to Texas, furnishing over 50 per cent of the pine timber cut in the South—the timber par excellence for heavy construction, but also useful for flooring and in other directions where strength and wearing qualities are required.

(2) The Cuban pine (*Pinus heterophylla*), found especially in the southern portions of the long-leaf pine belt, known to woodsmen commonly as "slash pine," but not distinguished in the lumber market. It is usually mixed in with long leaf, which it closely resembles, although it is wider ringed (coarse grained), and to which it is equal if not superior in weight and strength.

(3) The short-leaf pine (*Pinus echinata*), also known, besides many other names, as yellow pine and as North Carolina pine, but growing through all the Southern States generally north of the long leaf pine region; much softer and with much more sapwood than the former two, useful mainly for small dimensions and as finishing wood, being about 20 per cent weaker than the long-leaf pine.

(4) The loblolly or old-field pine (*Pinus tæda*), of similar although more Southern range than the short leaf, also known as Virginia pine, much used locally and in Washington and Baltimore, destined to find more extensive application. At present largely cut together with short leaf and sold with it as "yellow pine," or North Carolina pine, without distinction, although sometimes far superior, approaching long-leaf pine in strength and general qualities.

The names in the market are often used interchangeably and the materials in the yard mixed. All four species grow into tall but slender trunks, as a rule not exceeding 30 inches in diameter and 100 feet in height; the bulk of the logs cut at present fall below 20 inches. The sapwood forms in old trees of long leaf (with 2 to 4 inches) about 40 per cent of the total log volume; in Cuban, short leaf, and loblolly 60 per cent and over.

A reliable microscopic distinction of the wood of the four species has not yet been found. As a rule long leaf contains much less sapwood than the other three. The narrow-ringed wood of long leaf (averaging 20 to 25 rings to the inch) usually separates it also from the other three, while the especially broad-ringed Cuban excels usually also by broader summer-wood bands. In the log short leaf and loblolly may usually be recognized as distinguished from the former by the greater proportion of sapwood and lighter color due to smaller proportion of summer wood. The general appearance of the wood of all four species is, however, quite similar. The annual rings (grain) are sharply defined; the light yellowish spring wood and the dark orange-brown summer wood of each ring being strongly contrasted produce a pronounced pattern, which, although pleasing, especially in the curly forms (which occur occasionally), may become obtrusive when massed.

The following diagnosis may prove helpful in the distinction of the wood:

Diagnostic features of the wood.

Name of species.	Long-leaf pine (*Pinus palustris* Miller).	Cuban pine (*Pinus heterophylla* (Ell) Sud).	Short-leaf pine (*Pinus echinata* Miller).	Loblolly pine (*Pinus tæda* Linn.).
Specific gravity of kiln-dried wood. Possible range	.50 to .90	.50 to .90	.40 to .80	.40 to .80
Specific gravity of kiln-dried wood. Most frequent range.	.55 to .65	.55 to .70	.45 to .55	.45 to .55
Weight, pounds per cubic foot, kiln-dried wood. (Average)	36	37	30	31
Character of grain seen in cross section	Fine and even; annual rings quite uniformly narrow; on large logs averaging generally 20 to 25 rings to the inch.	Variable and coarse, rings mostly wide; averaging on large logs 10 to 20 rings to the inch.	Very variable; medium, coarse; rings wide near heart, followed by zone of narrow rings; not less than 4 (mostly about 10 to 15) rings to the inch, but often very fine grained.	Variable, mostly very coarse; 3 to 12 rings to the inch, generally wider than in the short leaf.
Color, general appearance	Even dark reddish yellow to reddish brown.	Dark straw color with tinge of flesh color.	Whitish to reddish or yellowish brown.	Yellowish to orange brown.
Sapwood, proportion	Little; rarely over 2 to 3 inches of radius.	Broad; 3 to 6 inches	Commonly over 4 inches of radius.	Very variable, 3 to 6 inches of the radius.
Resin	Very abundant; parts often turning into "light wood;" pitchy throughout.	Abundant, sometimes yielding more pitch than long leaf; "bleeds" freely, yielding little scrape.	Moderately abundant, least pitchy; only near stumps, knots, and limbs.	Abundant; more than short leaf, less than long leaf and Cuban, but does not "bleed" if tapped.

The sapling timber of all four species is coarse grained, that of loblolly exceeding the rest in this respect. The grain varies most in the butt, least in the top, is very fine in the outer portions of all old trees. Loblolly in the center of the log frequently shows rings over one-half inch wide, and timber averaging eight rings to the inch is not rare, while short leaf will average 10 to 15 rings to the inch. The greater or less proportion of the sharply defined dark-colored bands of summer wood of the ring furnish the most reliable and ready means of determining quality.

At present distinction is but rarely made in the species and in their use. All four species are used much alike, although differentiation is very desirable on account of the difference in quality. Formerly these pines, except for local use, were mostly cut or hewn into timbers, but especially since the use of dry kilns has become general and the simple oil finish has displaced the unsightly painting and "graining" of wood Southern pine is cut into every form and grade of lumber. Nevertheless, a large proportion of the total cut is still being sawed to order in sizes above 6 by 6 inches, and lengths above 20 feet for timbers, for which the long leaf and Cuban furnish ideal material. The resinous condition of these two pines make them also desirable for railway ties of lasting quality.

MECHANICAL PROPERTIES.

In general the wood of all these pines is heavy for pine (31 to 40 pounds per cubic foot, when dry); soft to moderately hard (hard for pine), requiring about 1,000 pounds per square inch to indent one-twentieth inch; stiff, the modulus of elasticity being from 1,500,000 upward; strong, requiring from 7,000 pounds per square inch and upward to break in bending, and over 5,000 pounds in compression when yard-dry.

The values given in this circular are averages based on a large number of tests, from which only defective pieces are excluded.

In all cases where the contrary is not stated the weight of the wood refers to kiln-dried material and the strength of wood containing 15 per cent moisture, which may be conceived as just on the border of air-dried condition. The first table gives fairly well the range of strength of commercial timber.

Average strength of Southern pine.

Air-dry material (about 15 per cent moisture).

Name.	Compression strength.					Bending strength.								Tensile strength.	Shearing strength.
	With grain.				Across grain. 3 per cent indentation.	At rupture modulus $\frac{3\,Wl}{2\,bh^2}$				At elastic limit modulus $\frac{3\,W_1 l}{2\,bh^2}$	Elasticity (stiffness) modulus $\frac{3\,Wl^3}{4\,\Delta\,bh^3}$	Relative elastic resilience.			
	Average of all valid tests.		Average for the weakest one-tenth of all the tests.			Average of all valid tests.		Average for the weakest one-tenth of all the tests.							
	Absolute.	Relative.	Absolute.	Relative.		Absolute.	Relative.	Absolute.	Relative.						
	Lbs. per sq. inch.		*Lbs. per sq. inch.*		*Lbs. per sq. inch.*	*Lbs. per sq. inch.*		*Lbs. per sq. inch.*		*Lbs. per sq. inch.*	*Lbs. per sq. inch.*	*In.-lbs. per cu. in.*		*Lbs. per sq. inch.*	*Lbs. per sq. inch.*
Cuban pine	7,850	100	6,500	100	1,050	11,950	100	8,750	100	9,450	2,305,000	2.5		14,300	680
Longleaf pine	6,850	87	5,650	87	1,060	10,900	91	8,800	101	8,500	1,890,000	2.3		15,200	706
Loblolly pine	6,500	83	5,350	82	990	10,100	84	8,100	92	8,150	1,950,000	2.25		14,400	690
Shortleaf pine	5,900	75	4,800	74	940	9,230	77	7,000	80	7,200	1,600,000	2.05		13,400	688

RELATION OF STRENGTH TO WEIGHT.

The intimate relation of strength and specific weight has been well established by the experiments. The average resnlts obtained in connection with the tests themselves were as follows:

	Cuban.	Longleaf.	Loblolly.	Shortleaf.
Transverse strength	100	91	84	77
Specific weight of test pieces	100	94	82	77

Since in the determination of the specific gravity above given, wood of the same per cent of moisture (as is the case of the values of strength) was not always involved, and also since the test pieces, owing to size and shape, can not perfectly represent the wood of the entire stem, the following results of a special inquiry into the weight of the wood represents probably more accurately the weight and with it the strength-relations of the four species.

WEIGHT RELATIONS.

[These data refer to the average specific weight for all the wood of each tree, only trees of approximately the same age being involved.]

	Cuban.	Longleaf.	Loblolly.	Shortleaf.
Average age of trees	171	127	137	131
Number of trees involved	6	22	14	10
Specific gravity of dry wood	0.63	0.61	0.53	0.51
Weight per cubic foot	39	38	33	32
Relative weight	100	97	84	81
(Transverse strength *a*)	(100)	(91)	(84)	(77)

a The values of strength refer to all tests and therefore involve trees of wide range of age and consequently of quality, especially those of longleaf, involve much wood of old trees, hence the relation of weight and strength appears less distinct.

From these results, although slightly at variance, we are justified in concluding that Cuban and longleaf pine are nearly alike in strength and weight and excel loblolly and shortleaf by about 20 per cent. Of these latter, contrary to common belief, the loblolly is the heavier and stronger.

The weakest material wonld differ from the average material in transverse strength by about 20 per cent and in compression strength by about 30 to 35 per cent, except Cuban pine, for which the difference appears greater in transverse and smaller in compression strength. It must, of conrse, not be overlooked that these figures are obtained from full-grown trees of the virgin forest, that strength varies with physical conditions of the material and that, therefore, an intelligent inspection of the stick is always necessary before applying the values in practice. They can only represent the average conditions for a large amount of material.

DISTRIBUTION OF WEIGHT AND STRENGTH THROUGHOUT THE TREE.

In any one tree the wood is lighter and weaker as we pass from the base to the top. This is true of every tree and of all four species. The decrease in weight and strength is most pronounced in the first 20 feet from the stump and grows smaller upward. (See fig. 91.)

This great difference in weight and strength between butt and top finds explanation in the relative width of the summerwood. Since the specific weight of the dark summerwood band in each ring is in thrifty growth from .90 to 1.00, while that of the springwood is only about .40, the relative amount of summerwood furnishes altogether the most delicate and accurate measure of these differences of weight as well as strength, and hence is the surest criterion for ocular inspection of quality, especially since this relation is free from the disturbing influence of both resin and moisture contents of the wood, so conspicuous in weight determinations.

The following figures show the distribution of the summerwood in a single tree of longleaf pine, as an example of this relation:

	In the 10 rings next to the bark.	In the 10 rings, Nos. 100 to 110 from bark.	Average for entire disk.	Specific weight.
	Per cent.	*Per cent.*	*Per cent.*	
At the stump	37	52	50	0.73
32 feet from stump	25	38	33	59
87 feet from stump	15	37	26	55

Weight and strength of wood at different heights in the tree.

	Strength of longleaf pine (pounds per square inch).		Specific weight.			Mean of all three species. Relative weight.	Relative strength of longleaf pine. Mean of compression and bending.
	Bending strength.	Compression endwise (with grain).	Longleaf.	Loblolly.	Shortleaf.		
Number trees used	56		22	14	12	48	56
Average age of trees	150 (over)		127	113	131		
Number of feet from stump:							
0	....	....	.751 *106*	.629 *106*	.614 *105*	*106*	....
6	12,100 *100*	7,350 *100*	.705 *100*	.595 *100*	.585 *100*	*100*	*100*
10	11,650 *96*	7,200 *98*	.674 *96*	.578 *97*	.565 *97*	*97*	*97*
20	10,700 *88*	6,800 *93*	.624 *89*	.534 *90*	.523 *90*	*90*	*90*
30	10,100 *84*	6,500 *89*	.590 *84*	.508 *86*	.496 *85*	*85*	*86*
40	9,500 *79*	6,300 *86*	.560 *80*	.491 *83*	.472 *81*	*81*	*82*
50	9,000 *75*	6,150 *83*	.539 *77*	.476 *80*	.455 *78*	*78*	*79*
60	8,600 *71*	6,050 *82*	.528 *75*	.470 *79*	.454 *78*	*77*	*76*

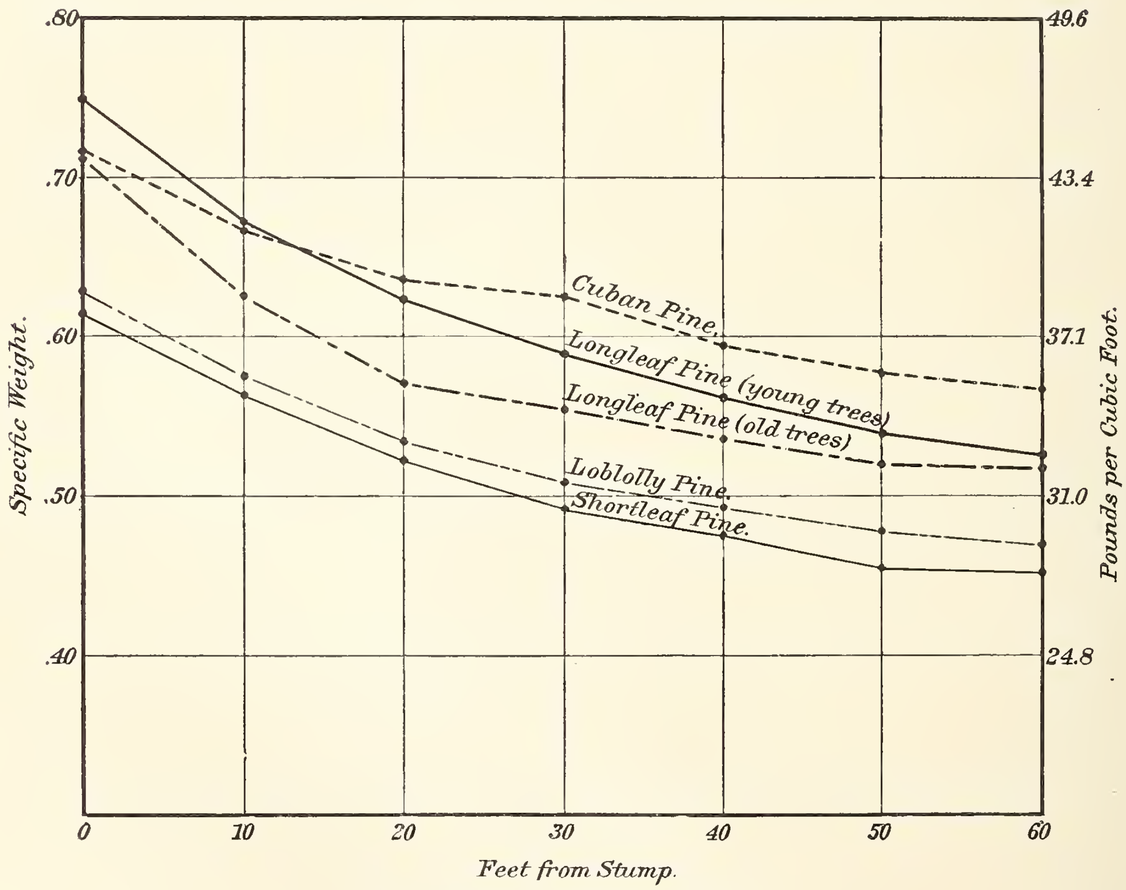


FIG. 91.—Variation of weight with height of tree.

Logs from the top can usually be recognized by the larger percentage of sapwood and the smaller proportion and more regular outlines of the bands of summer wood, which are more or less wavy in the butt logs.

The variation of weight is well illustrated in the foregoing table, in which the relative values are indicated in italics. For comparison the figures for strength of long-leaf pine are added.

Both weight and strength vary in the different parts of the same cross section from center to periphery, and though the variations appear frequently irregular in single individuals, a definite law of relation is nevertheless discernible in large averages, and once determined is readily observable in every tree.

A separate inquiry, avoiding the many variables which enter in the mechanical tests, permits the following deductions for the wood of these pines, and especially for long leaf, the data referring to weight, but by inference also to strength:

1. The variation is greatest in the butt log (the heaviest part) and least in the top logs.

2. The variation in weight, hence also in strength, from center to periphery depends on the rate of growth, the heavier, stronger wood being formed during the period of most rapid growth, lighter and weaker wood in old age.

3. Aberrations from the normal growth, due to unusual seasons and other disturbing causes, cloud the uniformity of the law of variation, thus occasionally leading to the formation of heavier, broad-ringed wood in old, and lighter, narrow-ringed wood in young trees.

4. Slow-growing trees (with narrow rings) do not make less heavy, nor heavier, wood than thriftily grown trees (with wide rings) of the same age. (See fig. 92.)

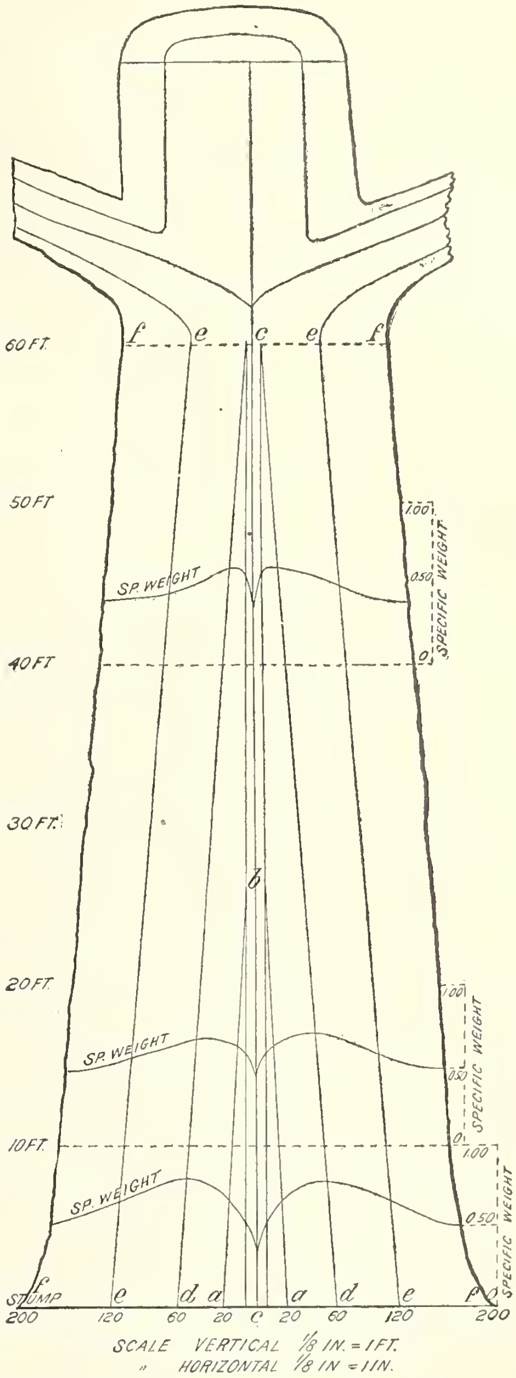


FIG. 92.—Schematic section through stem of long-leaf pine, showing variation of specific weight, with height, diameter, and age, at 20 (*aba*), 60 (*dcd*), 120 (*ecec*), 200 (*ffff*) years.

EFFECT OF AGE.

The interior of the butt log, representing the young sapling of less than 15 or 20 years of age, and the central portion of all logs containing the pith and 2 to 5 rings adjoining is always light and weak.

The heaviest wood in long-leaf and Cuban pine is formed between the ages of 15 and 120 years, with a specific weight of over 0.60 and a maximum of 0.66 to 0.68 between the ages of 40 and 60 years. The wood formed at the age of about 100 years will have a specific weight of 0.62 to 0.63, which is also the average weight for the entire wood of old trees. The wood formed after this age is lighter, but does not fall below 0.50 up to the two hundredth year; the strength varies in the same ratio.

In the shorter-lived loblolly and short leaf the period for the formation of the heaviest wood is between the ages of 15 and 80, the average weight being then over 0.50, with a maximum of 0.57 at the age of 30 to 40. The average weight for old trees (0.51 to 0.52) lies about the seventy-fifth year, the weight then falling off to about 0.45 at the age of 140, and continuing to decrease to below 0.38 as the trees grow older.

That these statements refer only to the clear portions of each log, and are variably affected at each whorl of knots (every 10 to 30 inches) according to their size, and also by the variable amounts of resin (up to 20 per cent of the dry weight), must be self-evident.

Sapwood is not necessarily weaker than heartwood, only usually the sapwood of the large-sized trees we are now using is represented by the narrow-ringed outer part, which was formed during the old-age period of growth, when naturally lighter and weaker wood is made; but the wood formed during the more thrifty diameter growth of the first eighty or one hundred years—sapwood at the time, changed into heartwood later—was, even as sapwood, the heaviest and strongest.

RANGE OF VALUES FOR WEIGHT AND STRENGTH.

Although the range of values for the individual tree of any given species varies from butt to top and from center to periphery by 15 to 25 per cent and occasionally more, the deviation from average values from one individual to another is not usually as great as has been believed; thus of 56 trees of long-leaf pine, 42 trees varied in their average strength by less than 10 per cent from the average of all 56.

The following table of weight (which is a direct and fair indication of strength), representing all the wood of the stem and excluding knots and other defects, gives a more perfect idea of the range of these values:

Range of specific weight with age (kiln-dried wood).

[To avoid fractions the values are multiplied by 100.]

	Cuban.	Longleaf.	Loblolly.	Short leaf.
Number of trees involved	24	96	60	56
Trees over 200 years old	61	57	....	....
Trees 150-200 years old	63	59	50	....
Trees 100-150 years old	....	60.5	53	51
Trees 50-100 years old	61	62	53.4	55
Trees 25-50 years old	55	61	53	57
Trees under 25 years old	51	55	48	53

Though occasionally some very exceptional trees occur, especially in loblolly and short leaf, the range on the whole is generally within remarkably narrow limits, as appears from the following table:

Range of specific weight in trees of the same age approximately; averages for whole trees.

[Specific gravity multiplied by 100 to avoid fractions.]

Name.	No. of trees.	Age (years).	Single trees.													Average.
Cuban	4	150-200	56	68	62	65	..	..	..	..	..	..	..	..	..	62.5
	5	50-100	60	58	60	59	67	..	..	..	..	..	..	..	..	60.9
Long-leaf pine	13	100-150	59	66	57	62	66	58	59	57	57	66	59	62	57	60.5
Loblolly pine	10	125-150	51	51	53	51	55	53	54	55	55	52	..	..	..	52.8
Short-leaf pine	12	100-150	45	47	53	47	50	51	55	55	53	51	50	53	..	50.8

From this table it would appear that single individuals of one species would approximate single individuals of another species so closely that the weight distinction seems to fail, but in large numbers—for instance, carloads of material—the averages above given will prevail.

INFLUENCE OF LOCALITY.

In both the Cuban and long-leaf pine the locality where grown appears to have but little influence on weight or strength, and there is no reason to believe that the long-leaf pine from one State is better than that from any other, since such variations as are claimed can be found on any 40-acre lot of timber in any State. But with loblolly, and still more with short leaf, this seems not to be the case. Being widely distributed over many localities different in soil and climate, the growth of the short-leaf pine seems materially influenced by location. The wood from the Southern coast and Gulf region, and even Arkansas, is generally heavier than the wood from localities farther north. Very light and fine-grained wood is seldom met near the southern limit of the range, while it is almost the rule in Missouri, where forms resembling the Norway pine are by no means rare. The loblolly, occupying both wet and dry soils, varies accordingly.

INFLUENCE OF MOISTURE.

This influence is among the most important; hence all tests have been made with due regard to moisture contents. Seasoned wood is stronger than green and moist wood. The difference between green and seasoned wood may amount to 50 and even 100 per cent. The influence of seasoning consists in (1) bringing by means of shrinkage about 10 per cent more fibers into the same square inch of cross section than are contained in the wet wood; (2) shrinking the cell wall itself by about 50 per cent of its cross section, and thus hardening it, just as the cow skin becomes thinner and harder by drying.

In the following tables and diagram this is fully illustrated. The values presented in these tables and diagrams are based on large numbers of tests and are fairly safe for ordinary use. They still require further revision, since the relations to density, etc., have had to be neglected in this study.

Influence of moisture on strength.

Average of all valid tests.	Per cent of moisture.a	Cuban.	Longleaf.	Loblolly.	Shortleaf.
Bending strength	33	8,450	7,660	7,370	6,900
	20	10,050	8,900	8,650	8,170
	15	11,950	10,900	10,100	9,230
	10	15,300	14,000	12,400	11,000
Crushing endwise	33	5,000	4,450	4,170	4,160
	20	6,600	5,450	5,350	5,100
	15	7,850	6,850	6,500	5,900
	10	9,200	9,200	8,650	7,000

Relative values.	Per cent of moisture.a	Cuban.	Longleaf.	Loblolly.	Shortleaf.	Average.
Bending strength	33	100	100	100	100	100
	20	118	116	117	118	117
	15	142	142	138	134	139
	10	181	182	168	160	173
Crushing endwise	33	100	100	100	100	100
	20	132	122	128	122	126
	15	157	154	156	142	152
	10	184	206	206	168	191
Mean of both bending and crushing strength	33	100	100	100	100	100
	20	125	119	122	120	122
	15	149	148	147	138	146
	10	182	194	187	164	182

a 33 per cent green, 20 per cent half dry, 15 per cent yard dry, 10 per cent room dry.

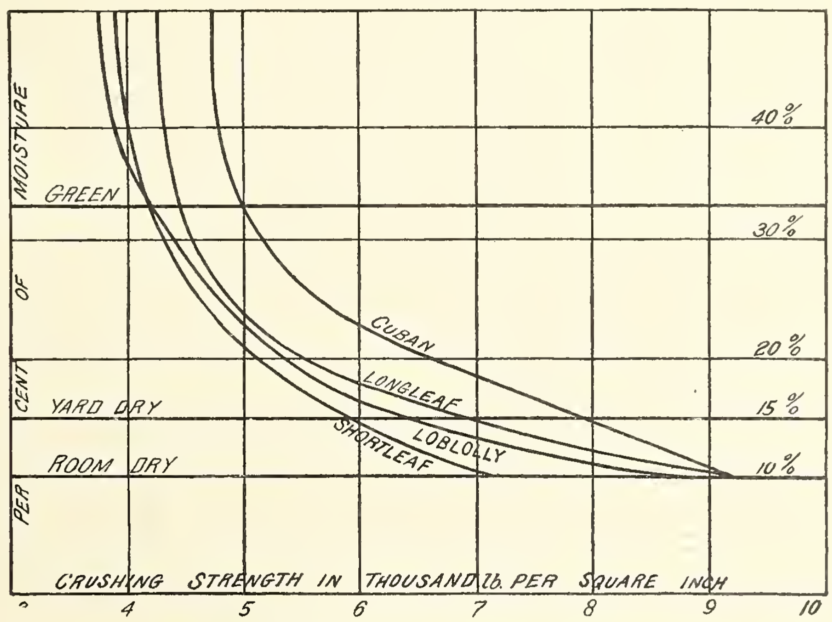


FIG. 93.—Variation of compression strength with moisture.

It will be observed that the strength increases by about 50 per cent in ordinary good yard seasoning, and that it can be increased by about 30 per cent more by complete seasoning in kiln or house.

Large timbers require several years before even the yard-season condition is attained, but 2-inch and lighter material is generally not used with more than 15 per cent moisture.

WEIGHT AND MOISTURE.

So far the weight of only the kiln-dry wood has been considered. In fresh as well as all yard and air-dried material there is contained a variable amount of water. The amount of water contained in fresh wood of these pines forms more than half the weight of the fresh sapwood, and about one-fifth to one-fourth of the heartwood; in yard-dry wood it falls to about 12 to 18 per cent, while in wood kept in well-ventilated and especially in heated rooms it is about 5 to 10 per cent, varying with size of piece, part of tree, species, temperature, and humidity of air. Heated to 150° F. (65° C.) the wood loses all but about $1\frac{1}{2}$ to 2 per cent of its moisture, and if the temperature is raised to 175° F. there remains less than 1 per cent, the wood dried at 212° F. being assumed to be (though it is not really) perfectly dry. Of course large pieces are in practice never left long enough exposed to become truly kiln-dry, though in factories this state is often approached.

As long as the water in the wood amounts to about 30 per cent or more of the dry weight of the wood there is no shrinkage[1] (the water coming from the cell lumen) and the density or specific gravity changes simply in direct

[1] In ordinary lumber and all large size material the exterior parts commonly dry so much sooner than the bulk of the stick that checking often occurs, though the moisture per cent of the whole stick is still far above 30.

proportion to the loss of water. When the moisture per cent falls below about 30 the water comes from the cell wall, and the loss of water and weight is accompanied by a loss of volume, so that both factors of the fraction

$$\text{Specific gravity} = \frac{\text{weight}}{\text{volume}}$$

are affected and the change in the specific gravity no longer is simply proportional to the loss of water or weight. The loss of weight and volume, however, being unequal and disproportionate, a marked reduction of the specific gravity takes place, amounting in these pines to about 8 to 10 per cent of the specific weight of the dry wood.

SHRINKAGE.

The behavior of the wood of the southern pines in shrinkage does not differ materially. Generally the heavier wood shrinks the most, and sapwood shrinks about one-fourth more than heartwood of the same specific weight. Very resinous pieces ("light wood") shrink much less than other wood. In keeping with these general facts, the shrinkage of the wood of the upper logs is usually 15 to 20 per cent less than that of the butt pieces, and the shrinkage of the heavy heartwood of old trees is greater than that of the lighter peripheral parts of the same, while the shrinkage of the heavy wood of saplings is greatest of all. On the whole, the wood of these pines shrinks about 10 per cent in its volume, 3 to 4 per cent along the radius, and 6 to 7 per cent along the tangent or along the yearly rings.

After leaving the kiln the wood at once begins to absorb moisture and to swell. In an experiment with short pieces of loblolly and shortleaf, representing ordinary flooring or siding sizes, these regained more than half the water and underwent more than half the total swelling during the first 10 days after leaving the kiln (see fig. 94). Even in this less than air-dry wood the changes in weight far excel the changes in volume (sum of radial and tangential swelling), and therefore the specific gravity, even at this low per cent of moisture, was decreased by drying and increased by subsequent absorption of moisture. Immersion and, still more readily, boiling, cause the wood to return to its original size, but temperatures even above the boiling point do not prevent the wood from "working," or shrinking, and swelling.

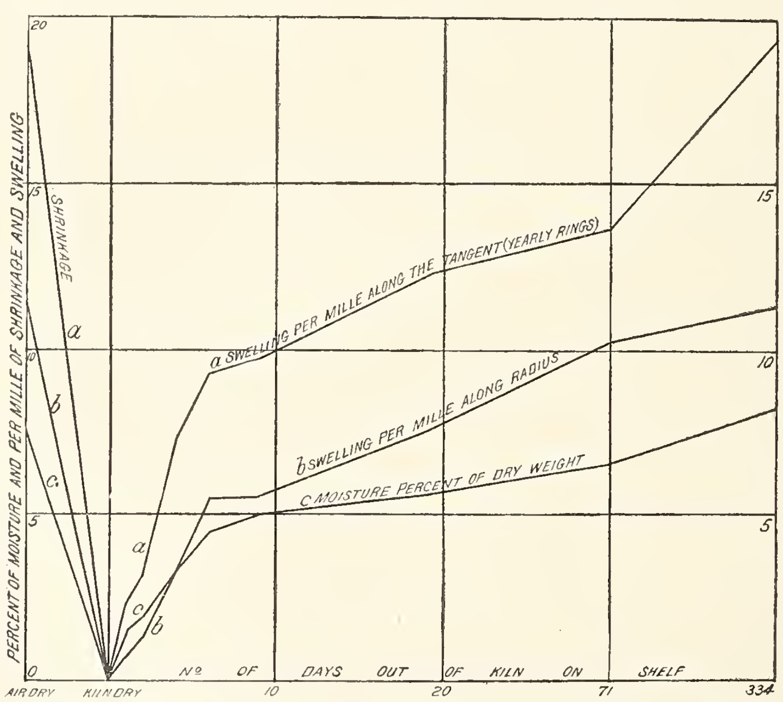


FIG. 94.—Loss of water in kiln drying and reabsorption in air, shrinking, and swelling.

In fig. 94 are represented the results of experiments on the rate of loss of water in the dry kiln and the reabsorption of water in the air. The wood used was of loblolly and shortleaf pine kept on a shelf in an ordinary room before and after kiln-drying. The measurements were made with caliper.

EFFECT OF KILN-DRYING.

Although kiln-drying has become quite universal, opinions are still divided as to its effects upon the strength of the material and other qualities. Many objections and claims as to physical and chemical changes produced by the treatment remain unsubstantiated. The method most widely used and most severely criticised is that of the "blower" kiln, where hot air (180° F.) is forced into the drying room by means of powerful fans. Besides the

many, in part, unreasonable and contradictory claims about closing or opening of pores, chemical or physical influence on the sap and its contents, albumen, gum, resin, sugar, etc., substances whose very existence in many cases is problematical or doubtful, the general claims of increased checking and warping, "casehardening," "honeycombing," etc., as well as reduction of strength, are still prevalent even among the very manufacturers themselves. The manner and progress of the kiln-drying may render this otherwise useful method of seasoning injurious. Rapid drying of the heavier hardwoods of complicated structure, especially in large sizes and from the green state, is apt to produce inordinate checking and thus weakening of the material. For Southern pine, however, it is entirely practicable to carry on the process without any injury, as is evidenced by the following experiment, in which wood of Cuban pine in small dimensions (4 by 4) was seasoned in warm air (about 100° F.) and parts of the same scantling were dried at temperatures varying from 150° at the entrance end to 190° F. at the exit:

	Bending strength.		Compression strength.
	Absolute.	At elastic limit.	
	Lbs. per sq. in.	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Mean of material not kiln-dried (reduced to 15 per cent of moisture)	12,200	9,070	7,630
Average of kiln-dry material	11,500	9,180	8,550

Well-constructed "blower kilns," where the hot air is blown in at one end and escapes at the other (this latter always the entrance end for the material), are giving satisfaction. The best kiln, however, seems to be one in which ample piping in the kiln itself insures sufficiently high (up to 180° F.), uniform temperature in all parts of the kiln, and where the circulation, promoted by a suction fan, is moderate and under perfect control. In such kilns even timbers of large size can be dried satisfactorily with a temperature not over 150° F.

EFFECT OF HIGH-TEMPERATURE AND HIGH-PRESSURE PROCESSES.

For some time a process employing high temperature under high pressure (temperature over 300° F., pressure 150 pounds) has been discussed and applied, claiming as a result of the treatment (1) increase in strength; (2) increase in durability; (3) absence of shrinkage.

The result of a series of experiments in which a number of scantlings of longleaf pine, one half treated, the other untreated, is as follows:

	Bending strength.	Compression strength.
	Lbs. per sq. in.	*Lbs. per sq. in.*
Treated	7,770	5,600
Untreated	12,340	7,400

The same difference in favor of the untreated material obtained in every single case.

The chemical analyses performed on wood lying side by side along the same radius, being of the same annual rings and same position in tree, gave the following:

Per cent of rosin and phenols calculated to dry weight of wood.

	Tree No. 475.		Tree No. 476.		Average of both.	
	Treated.	Untreated.	Treated.	Untreated.	Treated.	Untreated.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Rosin:						
Sapwood	1.21	2.05	1.22	1.23	1.22	1.64
Heartwood	8.35	10.58	2.23	1.93	5.29	6.26
Phenols:						
Sapwood	0.061	0.083	0.045	0.083	0.053	0.083
Heartwood	0.290	0.180	0.070	0.058	0.180	0.119

It appears that the protective rosin is rather decreased by the treatment, and the antiseptic phenols not increased in an adequate amount to be of value since it requires at least 20 times as much heavy oil in wood impregnation to be effective. It is, however, possible that the change of color due to the process may be accomplished and be produced by the formation of empyreumatic bodies (allied to the humus substances) which may act as preservative against the attacks of fungi.

The claim that the shrinkage of the wood is favorably influenced by the process was not sustained by a series of experiments with oak and pine, which showed that the treated wood absorbs water from air or in the tub, swells and shrinks in the same manner and to about the same extent as the untreated wood.

EFFECT OF IMMERSION ON THE STRENGTH OF WOOD.

The notion frequently expressed is that "soaking wood by floating, rafting, etc., reduces its tendency to decay and shrinkage, but injures its strength." The same was claimed for boiling or steaming preparatory to bending. The last position was disproved by Peter Barlow in the first quarter of this century. The following figures (results of an experiment involving several hundred separate tests) disprove the former assertion.

The soaked wood was kept immersed six months, each piece having its check pieces from the same scantling, which were not subject to the same process, but were tested—one green and one dry. All soaked pieces were seasoned in dry kiln before testing. All values were reduced to 15 per cent moisture.

Loblolly pine.	Bending strength.	Compression strength.
	Lbs. per sq. in.	*Lbs. per sq. in.*
Soaked 6 months, and then dried	10, 820	6, 780
Not soaked (mean of green and dry tests)	10, 570	7, 060

EFFECT OF "BOXING" OR "BLEEDING."

"Bleeding" pine trees for their resin—to which only the longleaf and Cuban pine are subjected—has generally been regarded as injurious to the timber. Both durability and strength, it was claimed, were impaired by this process, and in the specifications of many architects and large consumers, such as railway companies, "bled" timber was excluded. Sin c the utilization of resin is one of the leading industries of the South, and since the process affects several millions of dollars' worth of timber every year, a special investigation involving mechanical tests, physical and chemical analyses of the wood of bled and unbled trees from the same locality were carried out by this division. The results prove concusively (1) that bled timber is as strong as unbled if of the same weight; (2) that the weight and shrinkage of the wood is not affected by bleeding; (3) that bled trees contain practically neither more nor less resin than unbled trees, the loss of resin referring only to the sapwood, and, therefore, the durability is not affected by the bleeding process.

The following table shows the remarkable numerical similarity between the average results for three groups of trees, the higher values of the unbled material being readily explained by the difference in weight:

Longleaf pine.	Number of tests.	Specific weight of test pieces.	Bending strength.	Compression strength.
			Lbs. per sq. in.	*Lbs. per sq. in.*
Unboxed trees	400	0. 74	12, 358	7, 166
Boxed and recently abandoned	390	0. 79	12, 961	7, 813
Boxed and abandoned 5 years	535	0. 76	12, 586	7, 575

The amount of resin in the wood varies greatly, and trees growing side by side differ within very wide limits. Sapwood contains but little resin (1 to 4 per cent), even in those trees in which the heartwood contains abundance. In the heartwood the resin forms from 5 to 24 per cent of the dry weight (of which about one-sixth is turpentine and can not be removed by bleeding), so that its quantity remains unaffected by the process. Bled timber, then, is as useful for all purposes as unbled.

To give an idea how necessary it is that a large series of material be tested before making statements of the strength of wood of any species, we reproduce one of the many tables contained in Bulletin 8, which at the same time exhibits the variation of strength throughout the tree and from tree to tree.

Comparative Strength of Different Trees of Longleaf Pine.

Specimens taken from first 20 feet of tree trunk reduced to 15 per cent moisture. The numbers given in light-faced type are the percentages; the several results are the average of all of that class.

[The tabulated values and averages of tests from butt cuts (from 12 to 20 feet long) of individual trees.]

Local conditions of growth.	1 Number of tree.	1 Age.	2 Dates of cutting and sawing.	3 Dates of green and dry tests.	4 Number of sticks tested.	5 Approximate dimension in inches.	6 Standard percentage of moisture.	7 Average specific gravity (not reduced for moisture).	8 Cross-bending tests. Modulus of rupture per square inch. $f=\frac{3\ Wl}{2b\ h^2}$	9 Cross-bending tests. Modulus of strength at elastic limit per square inch. $f=\frac{3\ Wl}{b\ h^2}$	10 Cross-bending tests. Modulus of elasticity. $E=\frac{3\ Wl^3}{4\Delta b\ h^3}$	11 Crushing strength endwise per square inch.	12 Crushing strength across the grain per square inch. For 3 per cent distortion.	13 Crushing strength across the grain per square inch. For 15 per cent distortion.	14 Tensile strength per square inch (not reduced for moisture).	15 Shearing strength per square inch.	16 Per cent each tree is of its group.	17 Per cent each tree is of its kind.	18 Per cent each group is of its kind.	19 Per cent each kind is of the whole, giving each kind equal weight.	20 Per cent each tree is of the whole.
									Pounds.	*Pounds.*		*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*					
Unboxed.	1	182	Nov., 1890 Feb., 1891	July, 1891 Aug., 1892	7	4x4x60	15	0.753	101.4 12,664	98.6 9,057	103.1 2,081,243	103.9 7,370	96.1 1,004	1,410	107.4 20,347	103.7 744	101.1	101.1			97.1
	2	196	Nov., 1890 Feb., 1891	July, 1891 July, Aug., 1892	6	4x4x60	15	0.763	98.0 12,244	97.6 8,962	95.2 1,922,260	99.1 7,031	95.9 1,002	1,327	82.2 15,564	87.8 630	94.6	94.6			90.9
	3	183	Nov., 1890 Feb., 1891	July, 1891 Aug., 1892	4	4x4x60	15	0.729	98.9 12,345	100.0 9,187	108.0 2,180,977	97.0 6,881	94.0 982	1,394	107.6 20,369	92.6 664	98.8	98.8	100		94.9
	4	189	Nov., 1890 Feb., 1891	July, Aug., 1891 July, Aug., 1892	7	4x4x60	15	0.739	99.3 12,398	103.9 9,548	84.9 1,714,700	103.0 7,311	104.8 1,095	1,741	102.1 19,332	100.9 724	102.1	102.1			98.1
	5	226	Nov., 1890 Feb., 1891	July, 1891	24	4x4x60	15	0.762	102.4 12,796	99.9 9,174	108.8 2,197,808	97.1 6,891	109.2 1,141		100.7 19,081	115.0 825	103.4	103.4			99.3
Unboxed.	16	202	Apr., 1891 June, 1891	July, Aug., 1891 July, 1892	15	4x4x60	15	0.773	95.0 11,616	95.2 8,506	92.7 1,826,229	102.5 7,417	114.8 1,145	1,488	102.4 18,464	85.5 742	98.1	98.1		96.6	94.2
	17	163	Apr., 1891 June, 1891	Aug., Sept., 1891 July, 1892	6	4x4x60	15	0.753	92.3 11,289	95.5 8,534	97.2 1,915,380	97.5 7,064	102.5 1,023	1,444	81.7 14,732	97.4 846	94.4	94.4			90.7
	18	210	Apr., 1891 June, 1891	Aug., Sept., 1891 July, 1892	3	4x4x60	15	0.734	90.8 11,098	88.0 7,863	91.9 1,811,600	95.8 6,929	85.7 855	1,216	77.5 13,977	95.2 827	89.5	89.5	100		86.0
	19	160	Apr., 1891 June, 1891	Aug., 1891 July, 1892	4	4x4x60	15	0.698	104.8 12,808	103.0 9,202	99.6 1,962,975	97.5 7,052	79.9 797	1,047	112.0 20,210	114.5 994	101.5	101.5			97.5
	20	110	Apr., 1891 June, 1891	Aug., Sept., 1891 July, 1892	4	4x4x60	15	0.782	117.2 14,326	118.2 10,555	118.6 2,338,745	106.7 7,713	117.1 1,168	1,931	126.4 22,792	107.4 933	116.5	116.5			111.9
Boxed five years before cutting.	52	......	Oct., 1891 Nov., 1891	Nov., Dec., 1891 Jan., July, 1892	40	4x4x60	15	0.661	89.3 11,240	91.8 8,682	91.9 1,696,570	90.0 6,817	83.4 1,063	1,303	81.8 13,593	81.1 710	87.1	85.3			87.5
	53	192	Oct., 1891 Nov., 1891	Nov., Dec., 1891 Jan., July, 1892	19	4x4x60	15	0.732	92.2 11,606	95.4 9,020	81.9 1,512,458	93.0 7,045	91.3 1,164	1,405	79.5 13,220	76.8 672	88.8	86.9			88.1
	54	180	Oct., 1891 Nov., 1891	Nov., 1891 July, 1892	8	4x4x60	15	0.804	101.3 12,756	98.7 9,332	103.7 1,913,175	96.8 7,332	108.9 1,388	1,866	116.3 19,340	103.4 905	104.1	101.9			104.4
	55	......	Oct., 1891 Nov., 1891	Nov., 1891 July, 1892	10	4x4x60	15	0.720	97.1 12,221	102.5 9,694	96.5 1,781,640	98.2 7,440	94.9 1,210	1,556	96.1 15,968	86.7 759	96.6	94.6			97.0
	56	......	Oct., 1891 Nov., 1891	Nov., Dec., 1891 July, Aug., 1892	8	4x4x60	15	0.787	110.4 13,893	104.4 9,874	112.7 2,080,875	107.6 8,172	95.3 1,214	1,598	110.2 18,327	108.8 952	106.6	104.4	97.9	103.4	107.1
	57	......	Oct., 1891 Nov., 1891	Nov., 1891 Aug., 1892	8	4x4x60	15	0.747	103.9 13,082	102.8 9,727	99.1 1,829,862	99.6 7,551	103.8 1,323	1,742	90.2 14,996	106.5 932	101.6	99.5			102.0
	58	......	Oct., 1891 Nov., 1891	Nov., 1891 Aug., 1892	8	4x4x60	15	0.767	100.4 12,634	101.0 9,549	106.1 1,959,075	104.1 7,884	100.0 1,274	1,639	116.1 19,306	105.4 922	103.9	101.7			104.3
	59	......	Oct., 1891 Nov., 1891	Nov., 1891 Aug., 1892	6	4x4x60	15	0.777	105.3 13,253	103.6 9,798	107.9 1,992,035	110.4 8,361	122.3 1,559	1,928	109.7 18,237	131.2 1,148	111.3	109.0			111.8

COMPARATIVE STRENGTH OF DIFFERENT TREES OF LONGLEAF PINE—Continued.

Specimens taken from first 20 feet of tree trunk reduced to 15 per cent moisture. The numbers given in light-faced type are the percentages; the several results are the average of all of that class—Continued.

	1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Local conditions of growth.	Number of tree.	Age.	Dates of cutting and sawing.	Dates of green and dry tests.	Number of sticks tested.	Approximate dimension in inches.	Standard percentage of moisture.	Average specific gravity (not reduced for moisture).	Cross-bending tests. Modulus of rupture per square inch. $f=\frac{3\,Wl}{2b\,h^2}$	Cross-bending tests. Modulus of strength at elastic limit per square inch. $f=\frac{3\,Wl}{b\,h^2}$	Cross-bending tests. Modulus of elasticity. $E=\frac{3\,Wl^3}{4\Delta b\,h^3}$	Crushing strength endwise per square inch.	Crushing strength across the grain per square inch. For 3 per cent distortion.	Crushing strength across the grain per square inch. For 15 per cent distortion.	Tensile strength per square inch (not reduced for moisture).	Shearing strength per square inch.	Per cent each tree is of its group.	Per cent each tree is of its kind.	Per cent each group is of its kind.	Per cent each kind is of the whole, giving each kind equal weight.	Per cent each tree is of the whole.
									Pounds.	*Pounds.*		*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*					
Recently boxed.	60	225	Oct., 1891	Nov., Dec., 1891.					100.9	101.9	99.6	99.8	103.5		96.7	88.0					
			Nov., 1891	Jan., Aug., 1892.	15	4x4x60..	15	0.767	**13,078**	**10,148**	**1,911,106**	**7,794**	**1,347**	**1,582**	**16,137**	**834**	**99.6**	**101.7**			**104.3**
	61	214	Oct., 1891	Nov., Dec., 1891.					103.2	98.8	98.7	97.9	98.3		103.7	99.3					
			Nov., 1891	Jan., Aug., 1892.	21	4x4x60..	15	0.788	**13,376**	**9,846**	**1,894,267**	**7,647**	**1,280**	**1,899**	**17,300**	**941**	**99.7**	**101.8**			**104.4**
	62	......	Oct., 1891	Dec., 1891					105.4	110.3	110.3	98.2	113.5		114.3	84.1					
			Nov., 1891	Aug., 1892	6	4x4x60..	15	0.816	**13,661**	**10,988**	**2,116,550**	**7,676**	**1,478**	**1,804**	**19,078**	**797**	**105.3**	**107.5**			**110.3**
	63	200	Oct., 1891	Nov., Dec., 1891.					86.8	85.7	85.1	92.4	96.9		70.0	88.5					
			Nov., 1891	Aug., 1892	8	4x4x60..	15	0.737	**11,255**	**8,536**	**1,633,450**	**7,220**	**1,262**	**1,711**	**11,681**	**839**	**87.0**	**88.8**			**91.1**
	64	......	Oct., 1891	Nov., Dec., 1891.					102.0	108.2	109.5	103.3	97.3		108.4	96.7			102.1	103.4	
			Nov., 1891	Aug., 1892	8	4x4x60..	15	0.835	**13,221**	**10,780**	**2,100,925**	**8,069**	**1,267**	**1,740**	**18,089**	**917**	**103.8**	**106.0**			**108.7**
	65	......	Oct., 1891	Nov., Dec., 1891.					98.8	97.7	93.8	103.9	100.5		110.5	114.8					
			Nov., 1891	Aug., 1892	8	4x4x60..	15	0.843	**12,799**	**9,736**	**1,798,750**	**8,041**	**1,309**	**1,769**	**18,442**	**1,088**	**101.9**	**104.0**			**106.7**
	66	91	Oct., 1891	Nov., Dec., 1891.					100.2	91.1	93.2	98.9	102.3		90.9	116.7					
			Nov., 1891	Aug., 1892......	4	4x4x60..	15	0.797	**12,981**	**9,077**	**1,789,000**	**7,733**	**1,332**	**1,816**	**15,165**	**1,106**	**98.2**	**100.2**			**102.8**
	67	116	Oct., 1891	Nov., Dec., 1891.					102.8	106.3	109.7	106.5	87.6		105.9	112.0					
			Nov., 1891	Aug., 1892	8	4x4x60..	15	0.781	**13,320**	**10,585**	**2,105,212**	**8,305**	**1,140**	**1,583**	**17,577**	**1,062**	**104.5**	**106.7**			**109.4**
									101.0	101.4	101.2	99.0	102.3		102.9	90.4					
Average of first group, 5 unboxed trees					....	....	....	0.749	**12,489**	**9,186**	**2,019,398**	**7,097**	**1,045**	**1,468**	**18,939**	**717**	**100.0**				
									99.0	98.6	98.8	101.0	97.7		97.6	109.6					
Average of second group, 5 unboxed trees					....	....	....	0.748	**12,227**	**8,932**	**1,970,986**	**7,235**	**998**	**1,425**	**18,035**	**868**	**100.0**				
									98.5	97.4	98.1	98.5	98.9		99.8	96.1					
Average of third group, 8 trees boxed 5 years before cutting.					....	....	....	0.762	**12,586**	**9,459**	**1,845,711**	**7,575**	**1,274**	**1,630**	**16,623**	**875**	**97.9**				
									101.5	102.6	101.9	101.5	101.1		100.2	103.9					
Average of fourth group, 8 trees recently boxed.					....	....	....	0.795	**12,961**	**9,962**	**1,918,657**	**7,813**	**1,302**	**1,738**	**16,684**	**948**	**102.1**				
									98.3	96.5	102.9	96.4	88.5		105.2	93.1	96.6				
Average of first and second groups, 10 unboxed trees.					....	....	....	0.749	**12,358**	**9,059**	**1,995,192**	**7,166**	**1,021**	**144**	**18,487**	**793**					
									101.7	103.5	97.1	103.6	111.5		94.8	106.9	103.4				
Average of third and fourth groups, 16 boxed trees.					....	....	....	0.779	**12,774**	**9,710**	**1,882,184**	**7,694**	**1,288**	**1,684**	**16,654**	**912**					
Mean value of boxed and unboxed trees					....	....	....	0.764	**12,566**	**9,385**	**1,938,688**	**7,430**	**1,155**	**1,565**	**17,570**	**853**					
Averages of all trees (26)					265	4x4x60..	15	0.767	**12,614**	**9,460**	**1,925,644**	**7,452**	**1,185**	**1,598**	**17,359**	**866**					

SIZE OF TEST MATERIAL.

The long-standing idea of engineers and other consumers to have wood tested more nearly in the sizes used in ordinary practice led to the adoption of test sizes, generally varying from 3 by 3 inches to 4 by 4 inches. Besides this, special inquiries with different kinds of timber into the relation of large and small tests were instituted to ascertain the correctness of the general dogma which claimed that tests on small pieces could not be utilized, since such pieces for their very size gave higher values of strength. This investigation involved full-size columns as well as beams, and was continued throughout the entire period of the timber-physics work. It led to a number of the most interesting and highly valuable results, as will appear from the following statements:

Selected tests of columns and compression pieces from the same trees compared.

Number of tree.	Length.	Ratio $\frac{l}{d}$	Small pieces (average of whole tree). (a)	Large columns. (b)	Relative value. (a)	(b)	Deflection.	Failure.
	Feet.		*Pounds per sq. inch.*	*Pounds per sq. inch.*			*Inch.*	
239	12	14	6,700	6,100	100	91	0.7	Sheared.
240	12	14	7,000	6,900	100	99	0.1	Compression.
241	12	15	6,900	6,500	100	94	0.7	Do.
309	12	12	6,800	6,500	100	96	0.4	Do.
312	12	16	6,100	6,300	100	103	0.4	Do.

In these columns (nearly one-tenth of all longleaf pine columns tested) the strength was so nearly the same as that of the short pieces that it appears as if flexure had but little to do with the failure, the small differences being amply accounted for by a larger number of defects in the columns. Should this prove true in general for wooden columns as ordinarily designed, the problem would become simply a study of the influence of defects and of proper inspection.

The nature of the failures would also point in this direction:

Of 86 columns 32 failed normally, i. e., in simple compression; 22 were crushed near the end; 14 failed at knots, and 19 by shearing, the rupture usually beginning at or near the ends; a small knot proved sufficient to cause a large column, 20 times as long as its diameter, to fail at 14 inches from the end.

The deflection in the average for all columns (12 to 20 feet long) was only about 1 inch for the maximum load, when, to be sure, destruction had progressed for some time; at the elastic limit the deflection was only about one-half as much. These results would seem to warrant the statement that for pine columns at least, in which the ratio of height to least diameter does not exceed 1 in 20, none of the accepted column formulæ are applicable, the nature of the failure being mostly in simple compression, and depending more on specific defects than on the design of the column.

STRENGTH OF LARGE BEAMS AND COLUMNS.

Owing to the fact that much wood testing has been done on small, select, and perfectly seasoned pieces, usually from butt logs, the values thus obtained seemed to differ very markedly from the results on large timbers usually very imperfectly seasoned, and it was claimed that tests on small sizes always furnished too high values, just as if the differences were due to sizes alone.

While, to be sure, a small piece may be so selected that defects are excluded, the grain straight and in the most favorable position with regard to the load, the assumption of the difference in strength of small pieces from that of large-sized sticks has never been made good experimentally.

Since it appears desirable to compare the results from large beams and columns not only with the average data obtained from the general test series on small 4 by 4 material, but also with the average strength of small pieces cut from the same beams and columns, a special inquiry into the legitimacy of such a comparison was made. This study involved over 100 separate tests, and proved the very important fact that uninjured parts of broken beams and columns do not suffer in the test. The large-sized beams varied from 4 by 4 to 8 by 16 inches.

Tests of large and small beams—Bending strength.

	Small beams, general test series.	Large beams. Total.	Large beams. Beams from which small beams were cut.	Small beams cut from large beams.
Number of tests involved	1,986	127	57	236
	Lbs. per sq. in.	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Longleaf	11,300	11,500	9,800	10,100
Loblolly	10,000	10,800	10,300	10,000
Shortleaf	9,300	9,200	8,700	8,700

From the preceding table it would appear that large timbers, when symmetrically cut (i. e., with the center of the log as center of the beam), develop as beams practically the same strength as the average of the small pieces that may be cut from them, and sometimes even higher values; the explanation being that cut in this manner the extreme fibers which are tested in a beam come to lie in that part of the tree which, as a rule, contains the strongest timber.

Results discordant from these may be explained by differences in the degree of seasoning of the outer layers and also by the fact that especially in the northern pineries timbers are often cut from the top logs, which are weaker and more defective.

Test of large and small columns—Compression strength.

	Regular series from same trees as the columns.	Columns (simple compression).	Small pieces cut from columns.
Number of tests involved	949	95	97
	Lbs. per sq. in.	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Longleaf	6,600	5,300	7,100
Loblolly	6,800	4,700	6,300
Shortleaf	5,900	4,100	6,200
Cuban	7,400	5,000	8,700

The square columns were mostly 8 by 8 inches, some 10 by 10 inches, a few of larger and also some of smaller dimensions. The ratio of length to width varied from 12 to 27, about one-half being under and the other half over 18 to 1. The compression pieces of the regular series, and those cut from the broken columns, were in general about 4 by 4 by 6 inches.

It will appear from this statement of average results that columns develop only from 62 per cent (in Cuban) to 78 per cent (longleaf) of the compression strength of ordinary short pieces. The explanation may be due to several reasons, natural and mechanical. In a column, unlike a beam, all the fibers are under great strain; hence all the defects, which are by necessity found in every column, influence the results; the flexure of a column under strain is an element of weakness, to which the short compression piece is not subject. In addition the difficulty of determining the average moisture condition of the large timber throughout the cross section and that of the small pieces cut from them afterwards would render this method for columns less satisfactory; a larger number of tests will still be required to establish comparable average conditions in the two kinds of tests. It would, therefore, be unsafe to generalize too hastily from these average figures, at least as to the numerical difference, for there are remarkable individual exceptions. Not only do individual columns show differences in strength 50 per cent and more lower than the compression pieces from the same log, but sometimes they show practically the same or even a higher value of strength, as will appear from the following selected cases, in which the data for the columns are placed in comparison with those obtained on compression pieces from the same tree.

Additional Series on Beams and Columns.

A series more extended as regards beams, involving 68 large and 777 small beams, besides over 1,000 compression tests on the same material on which the beam tests were made, and tests on 6 large columns, has fully confirmed the indications of the previous experiments.

TESTS ON COLUMNS.

The columns were 12 by 12 inches and 8 by 12 inches in cross section, with a length of 132 to 168 inches. From these were cut, as near as possible from the place of failure, two blocks 24 inches long, and these blocks were tested on the same large testing machine (described in Bulletin 6), so that inaccuracies of machinery do not enter into consideration. The results, tabulated as follows, prove conclusively the statement made upon the former more extensive series (see Circular 12), that wooden columns in which the diameter and length are to each other as 1 to 18 or less behave like short blocks and fail in simple compression. The four columns of long-leaf pine exhibit practically the same strength as the short blocks—i. e., within 10 per cent—which, as has been shown above, is within the limits of maximum uniformity.

Strength of large columns and short (24-inch) blocks cut from these columns.

Kind of wood.	Dimensions of columns (inches).			Moisture of wood (per cent).	Modulus of elasticity (pounds).	Compression strength in pounds per square inch.	
						Columns.	Short blocks.
Shortleaf pine	144	12	12	14.2	2,274,000	4,840	6,090
Do	132	12	12	12.9	1,740,000	4,840	5,660
Longleaf pine	168	12	8	30.9	1,628,000	2,940	2,950
Do	168	12	8	32.3	1,570,000	3,170	3,530
Do	156	12	8	40.8	1,764,000	3,030	3,310
Do	156	12	8	29.7	1,776,000	3,710	3,780

BEAM TESTS.

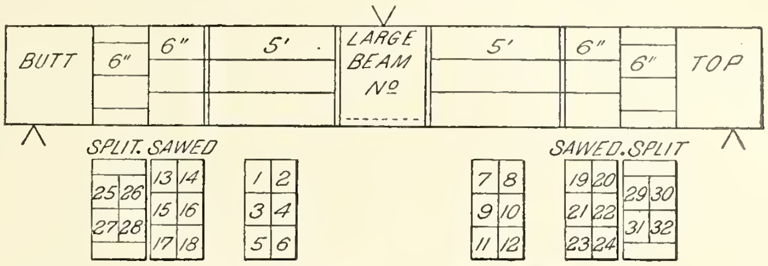
The experiments, of which the following tables contain the principal results, were performed on beams generally 8 by 12 by 192 inches. After breaking the large beam 12 small beams were cut from the uninjured portion of the large beam[1] in such a way that the entire cross section of the large piece was represented by two sets of 6 small beams each. Besides these tests on small beams, the compression strength of part of the material was tested on small blocks, part of which was sawed and part split from portions of the large beam. (See diagram at head of

[1] The legitimacy of using such material for such purpose has been fully established by a long series of experiments. (See Circular 12, Division of Forestry, p. 11.)

table.) To avoid any complications due to differences or changes in moisture, the tests on large and small beams were performed the same day.

Strength of large beams and of small beams, and of compression pieces cut from them.

[Usually 12 small beams cut from the uninjured part of each large beam.]



Kind of wood.	Number of beam.	Strength of large beams.	Average strength of small beams.	Moisture.		Compression, endwise strength.	
				Large beams.	Small beams.	Sawed pieces.	Split pieces.
		Lbs. per sq. in.	*Lbs. per sq. in.*	*Per cent.*	*Per cent.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Oak	1	7,400	8,560	69.5	68.5	3,960	4,120
	2	5,880	8,660	70.3	69.0	4,340	4,700
	3	6,570	6,220	75.3	75.2	3,030	3,190
	4	8,640	8,800	66.6	67.6	4,090	4,460
	5	8,150	7,710	64.8	65.8	3,680	3,750
	6	7,450	6,910	63.0	66.6	3,330	3,330
	8	6,870	6,890	67.4	70.5	3,470	3,190
Shortleaf pine	9	8,300	7,950	48.1	57.7	4,030	4,160
	10	7,440	7,250	42.1	56.3	3,840	3,850
	11	5,110	6,760	38.9	33.3	3,870	3,630
	12	7.360	6,930	35.2	33.5	3,890	3,850
	13	7,320	7,300	37.4	40.6	4,090	3,800
White pine	14	3,110	3,560	84.9	83.6	2,440	2,500
	15	4,280	4,340	43.8	41.2	2,710	2,840
	16	3,770	4,590	50.7	50.5	2,660	2,760
	17	3,460	3,590	60.0	48.6	2,410	2,570
	18	3,990	3,640	42.8	43.0	2,800	2,620
	19	4,040	4,400	62.4	60.4	2,760	2,780
	20	4,410	4,180	53.6	51.8	2,680	2,700
	21	4,900	4,320	50.1	51.0	3,010	2,900
	22	3,860	4,320	50.2	60.8	2,500	2,430
	23	4,660	4,890	52.0	58.2	2,850	2,880
	24	3,960	4,440	76.3	71.5	2,520	2,710
	25	3,920	4,410	53.6	60.5	2,840	2,730
Shortleaf pine	26	4,560	6,290	31.2	30.5	3,660	3,850
	27	4.390	5,610	33.9	36.0	2,830	3,110
	28	6,670	6,830	28.6	28.9	3,540	3,590
	29	7,410	7,630	28.6	29.0	4,450	4,250
	30	6,600	7,160	28.3	28.9	4,200	4,190
	31	5,750	6,000	34.3	35.5	3,630	3,530
	32	6,210	7,500	26.4	27.2	3,940	4,050
	33	7,450	8,390	29.5	30.1	4,350	4,220
	34	7,000	7,800	28.4	29.5	4,070	4,120
	35	6,030	6,740	28.8	29.4	3,810	3,640
	36	6,520	6,890	31.6	31.6	4,320	4,370
	37	7,030	7,890	29.2	29.9	4,380	4,920
	38	7,710	8,510	26.2	25.4	4,500	4,610
	39	8,090	8,210	32.5	31.9	4,550	4,670
	40	7,680	7,980	31.1	32.3	4,290	4,380
	41	7,330	8,230	31.7	31.5	4,680	4,820
Longleaf pine	42	7,290	8,740	30.9	31.2	4,950	5,120
	43	8,850	9,720	28.1	28.9	5,300	5,440
	44	8,040	8,870	26.3	26.9	4,730	5,070
	45	8,090	8,850	25.8	25.4	5,000	5,050
	46	7,620	7,670	32.6	33.9	4,730	4,830
	47	6,710	7,610	33.0	33.4	4,200	4,520
	48	8,480	8,300	29.3	29.3	4,870	4,890
	49	5,630	6,250	34.5	33.7	3,600	3,630
White pine	50	4,900	5,020	87.2	75.7	2,970	3,200
	51	5,300	5,210	71.4	69.6	3,330	3,240
	52	4,810	4,470	77.2	64.7	2,940	3,100
	53	3,610	3,610	54.5	58.2	2,400	2,550
	54	4,440	4,720	97.6	94.9	2,710	2,900
Shortleaf pine	55	6,400	7,610	27.0	27.1	4,340	4,500
	56	6,690	6,880	28.4	26.6	4,050	4,210
	57	6,670	6,990	27.0	26.4	4,100	4,340
	58	7,310	7,490	28.5	26.8	4,100	4,030
White pine	101	5,070	7,200	15.4	16.2	5,410	5,720
	102	6,340	6,890	11.0	11.7	4,920	5,520
	103	7,070	8,750	12.2	10.5	5,140	5,760
	104	4,900	6,680	12.1	8.2	4,360	4,700
	105	6,640	6,890	10.6	11.2	5,450	5,310
	106	6,180	7,650	11.6	11.3	5,190	5,420
	107	6,080	6,090	11.5	11.5	4,810	5,170
	108	5,510	5,810	11.1	10.7	5,100	4,710
	109	6,930	7,300	11.4	10.5	5,330	5,080
	110	5,930	6,010	12.1	11.6	4,600	4,670
	111	4,010	5,040	13.0	13.0	4,270	4,390

OBSERVATIONS AND DEDUCTIONS.

(*a*) The difference between the values for the large beam and the average for the small beams is not at all constant, either in character or quantity; the large beam may be stronger (20 per cent of the cases) or practically as strong—i. e., within 10 per cent (57 per cent of the cases)—or it may be weaker, and vary often considerably from the average (23 per cent of the cases).

Of 696 tests on small beams 235 furnished results smaller than that of the large beam. Again, out of 396 small beams fully 40 per cent were weaker that the large beam, while of another series of 300 only 24 per eent gave lower values.

(*b*) There are in every case some small beams which far excel in strength the large beam; even in such cases, where the average strength of the small beams is practically the same as that of the large beam, some small beams show values 25 to 30 per cent greater than the large beam.

(*c*) In only 6 per cent of the cases each of the small pieces gave a higher result than was obtained from the large beam, but in these cases the latter was evidently defective.

(*d*) In all beams the differences observed betwcen the several small beams themselves are far greater than that between the average value of the small beams and the value of the large beam from which they are cut.

From these observations, which are fully in accord with the observations on the numerous tests of the large general series, it would appear that—

(1) Size alone can not account for the differences observed; and, therefore, also that a small beam is not proportionately stronger because it is smaller, for it may be either stronger or weaker; but that if it is stronger, the cause of this lies in the fact that the larger beam contains weak as well as strong wood, besides other defects, which may or may not appear in the small stick.

(2) Generally, but not always, a large timber gives values nearer the average, since it contains, naturally, a larger quantity as well as a greater variety of the wood of the tree; and, therefore, also—

(3) Small beams, for the very reason of their smallness, containing, as they do, both a smaller quantity and variety of the material, give results which vary more from the average than results from large beams, and, therefore, can be utilized only if a sufficient number be tested; but it also appears that—

(4) To obtain an average value, even a very moderate number of smaller pieces, if they fairly represent the wood of the entire stem, give fully as reliable data as values derived from a large beam.

(5) *Average values derived from a large series of tests on small but representative material may be used in practice with perfect safety, and these averages are not likely to be modified by tests on large material.*

It might be added that both the practicability and need of establishing a coefficient or ratio between results from tests on large and small beams or columns falls away. To deserve any confidence at all, only a large series of tests on either large or small beams would satisfy the requirement of establishing standard values, while a series of small pieces has the preference, not only on account of greater cheapness and convenience in establishing the values, but still more for the reason that only by the use of small, properly chosen material is it possible to obtain a sufficiently complete representation of the entire log.

Before these results, part of which were published by installments, had all been computed and arranged, the results of the work made it possible to publish, for the first time in the English language, a brief exposition of the technical properties of wood in general, which appeared as Bulletin 10 of the Division. This little booklet was copied verbatim several times by different technical journals of this country, was embodied in toto in one of the best works on the materials of engineering, and was even translated into French by one of the foremost publishers of France, besides being used itself as a text book by several of our largest colleges. In addition to the discussions of the several technical properties of wood, this booklet contains the first attempt in the English language at a key by which our common woods may be safely recognized from their structure alone. The key and some of the tables in this bulletin have been reproduced in an earlier part of this report. By this time, when the work was interrupted by superior orders, there were brought together the strength values for the wood of 32 species, of which 26 were represented by more than 200 tests each (the longleaf pine by over 6,000), 17 of them by over 400 tests per species, and seven by over 1,000 tests. These results were published in full in Circular No. 15 of the Division, from which the following extract is here repeated:

SUMMARY OF MECHANICAL TESTS ON THIRTY-TWO SPECIES OF AMERICAN WOODS.

GENERAL REMARKS.

The chief points of superiority of the data obtained in these investigations lie in, (1) Correct identification of the material, it being collected by a competent botanist in the woods; (2) selection of representative trees with record of age, development, place and soil where grown, etc.; (3) determination of moisture conditions and specific gravity and record of position in the tree of the test pieces; (4) large number of trees and of test pieces from each tree; (5) employment of large and small-sized test material from the same trees; (6) uniformity of method for an unusally large number of tests.

The entire work of the mechanical test series, carried on through nearly six years intermittently as funds

were available, comprises so far 32 species with 308 test trees, furnishing over 6,000 test pieces, supplying material for 45,336 tests in all, of which 16,767 were moisture and specific gravity determinations on the test material.

In addition to the material for mechanical tests, about 20,000 pieces have been collected from 780 trees (including the 308 trees used in mechanical tests) for physical examination to determine structure, character of growth, specific gravity of green and dry wood, shrinkage, moisture conditions, and other properties and behavior.

In addition to the regular series of tests, the results of which are recorded in the subjoined tables, special series, to determine certain questions were planned and carried out in part or to finish, adding 4,325 tests to the above number.

Account of test material.

No.	Name of species.	Number of trees.	Number of mechanical tests.	Average specific gravity of dry wood.	Localities and number of trees from each.
1	Longleaf pine (Pinus palustris.)	68	6,478	0.61	Alabama, coast plain (22) *a*; uplands (6); hill district (6); Georgia, undulating uplands (6); South Carolina, coast plain (7); Mississippi, low coast plain (2); Louisiana, low coast plain, gravelly soil (7); sandy loam (6); Texas, low coast plain (6).
2	Cuban pine (Pinus heterophylla.)	12	2,113	.63	Alabama, coast plain (6); Georgia, uplands (1); South Carolina, coast (5).
3	Shortleaf pine (Pinus echinata.)	22	1,831	.51	Alabama, uplands (4); Missouri, low hilly uplands (6); Arkansas, low hilly uplands (6); Texas, uplands (6).
4	Loblolly pine (Pinus tæda.)	32	3,335	.53	Alabama, mountainous plateau (8); low coast plain (6); Arkansas, level flood plain (5); Georgia, level coast plain (6); South Carolina, low coast plain (7).
5	White pine (Pinus strobus.)	17	540	.38	Wisconsin, clay uplands (5); sandy soils (4); sandy loam (5); Michigan, level drift lands (3).
6	Red pine (Pinus resinosa.)	8	412	.50	Wisconsin, drift (5); Michigan (3).
7	Spruce pine (Pinus glabra.)	4	696	.44	Alabama, low coast plain.
8	Bald cypress (Taxodium distichum.)	20	3,396	.46	South Carolina, pine barren (6); river bottom (4); Louisiana, coast plain, border of lake (4); Mississippi, Yazoo bottom (3); upland (3).
9	White cedar (Chamæcyparis thyoides.)	4	354	.37	Mississippi, low plain.
10	Douglas spruce (Pseudotsuga taxifolia.)	......	225	.51	(From lumber yard.)
11	White oak (Quercus alba.)	12	1,009	.80	Alabama, ridges of Tennessee Valley (5); Mississippi, low plain (7).
12	Overcup oak (Quercus lyrata.)	10	911	.74	Mississippi, low plain (7); Arkansas, Mississippi bottoms (3).
13	Post oak (Quercus minor.)	8	256	.80	Alabama, Tennessee Valley (5); Arkansas, Mississippi bottom (3).
14	Cow oak (Quercus michauxii.)	11	935	.74	Alabama, Tennessee Valley (4); Arkansas, Mississippi bottoms (3); Mississippi, low plain (4).
15	Red oak (Quercus rubra.)	7	299	.73	Alabama, Tennessee Valley (5); Arkansas, Mississippi bottom (2). *b*
16	Texan oak (Quercus texana.)	3	479	.73	Arkansas, Mississippi bottom.
17	Yellow oak (Quercus velutina.)	5	222	.72	Alabama, Tennessee Valley (5).
18	Water oak (Quercus nigra.)	4	132	.73	Mississippi, low plain (4).
19	Willow oak (Quercus phellos.)	12	649	.72	Alabama, Tennessee Valley (5); Arkansas, Mississippi bottom (3); Mississippi, low plain (4).
20	Spanish oak (Quercus digitata.)	11	1,035	.73	Alabama, Tennessee Valley (5); Arkansas, Mississippi bottom (3); Mississippi, low plain (3).
21	Shagbark hickory (Hicoria ovata.)	6	794	.81	Mississippi, alluvial plain (3); limestone (3).
22	Mockernut hickory (Hicoria alba.)	4	300	.85	Mississippi, low plain.
23	Water hickory (Hicoria aquatica.)	2	197	.73	Do.
24	Bitternut hickory (Hicoria minima.)	4	100	.77	Do.
25	Nutmeg hickory (Hicoria myristicæformis.)	3	294	.78	Do.
26	Pecan hickory (Hicoria pecan.)	2	172	.78	Do.
27	Pignut hickory (Hicoria glabra.)	3	84	.89	Do.
28	White elm (Ulmus americana.)	2	91	.54	Mississippi, bottom.
29	Cedar elm (Ulmus crassifolia.)	3	201	.74	Arkansas, bottom.
30	White ash (Fraxinus americana.)	3	476	.62	Mississippi, bottom.
31	Green ash (Fraxinus lanceolata.)	1	45	.62	Do.
32	Sweet gum (Liquidambar styraciflua.)	7	508	.59	Arkansas, bottom (3); Mississippi, low plain (4).

a Sixteen of these were bled trees to study the effects of boxing.
b These two should probably be classed as Southern red oak. They were collected before the distinction was finally decided upon.
NOTE.—The values for specific gravity here given refer to "dry" wood of test material—i. e., wood containing variable amounts of moisture below 15 per cent; the moisture effect has therefore not been taken into account, but more careful experiments indicate that its influence on specific gravity at such low per cent is so small that it may be neglected for practical purposes.

As will be observed, some species, notably the Southern pines, have been more fully investigated, and the results on these (which have been published more in detail in Circular No. 12) may be taken as authoritative. With those species of which only a small number of trees have been tested this can be claimed only within limits and in proportion to the number of tests.

The great variation in strength which is noticeable in timber of the same species makes it necessary to accept with caution the result of a limited number of tests as representing the average for the species, for it may have happened that only all superior or all inferior material has been used in the tests. Hence we would not be entitled to conclude, for instance, that pignut hickory is 14 per cent stronger than shagbark, as it would appear in the table, for the 30 test pieces of the former may easily have been superior material. Only a detailed examination of the test pieces or a fuller series of tests would enlighten us as to the comparative value of the results.

The following data, therefore, are not to be considered as in any sense final values for the species, except where the number of trees and tests is very large:

Results of tests in compression endwise.

[Pounds per square inch.]

No.	Species.	Number of tests.	Highest single test.	Lowest single test.	Average highest 10 per cent of tests.	Average lowest 10 per cent of tests.	Average of all tests.	Proportion of tests within 10 per cent of average.	Proportion of tests within 25 per cent of average.
	Reduced to 15 per cent moisture.							*Per cent.*	*Per cent.*
1	Longleaf pine	1,230	11,900	3,400	8,600	5,700	6,900	53	90
2	Cuban pine	410	10,600	2,800	9,500	6,500	7,900	61	93
3	Shortleaf pine	330	8,500	4,500	7,600	4,800	5,900	47	90
4	Loblolly pine	660	11,200	3,900	8,700	5,400	6,500	49	84
	Reduced to 12 per cent moisture.								
5	White pine	130	8,500	3,200	6,800	4,000	5,400	49	93
6	Red pine	100	8,200	4,300	8,100	4,900	6,700	54	96
7	Spruce pine	170	10,000	4,400	8,800	5,600	7,300	66	95
8	Bald cypress	655	9,900	2,900	8,500	4,200	6,000	31	74
9	White cedar	87	6,200	3,200	6,000	4,400	5,200	79	99
10	Douglas spruce *a*	41	8,900	4,100	8,100	4,200	5,700	28	65
11	White oak	218	12,500	5,100	11,300	6,300	8,500	40	81
12	Overcup oak	216	9,100	3,700	8,600	6,000	7,300	70	95
13	Post oak	49	8,200	5,900	8,100	6,000	7,100	58	100
14	Cow oak	256	11,560	4,600	9,800	5,600	7,400	51	89
15	Red oak	57	9,700	5,400	9,200	5,500	7,200	36	94
16	Texan oak	117	11,300	5,800	9,800	6,900	8,100	62	98
17	Yellow oak	40	8,600	5,500	8,300	5,800	7,300	58	100
18	Water oak	31	9,200	6,200	9,000	6,300	7,800	75	100
19	Willow oak	153	11,000	4,200	8,700	5,500	7,200	51	88
20	Spanish oak	251	10,600	3,700	9,500	5,100	7,700	61	94
21	Shagbark hickory	137	13,700	5,800	10,900	7,500	9,500	79	97
22	Mockernut hickory	75	12,200	6,200	11,600	8,000	10,100	65	99
23	Water hickory	14	10,000	6,700	9,600	7,000	8,400	71	100
24	Bitternut hickory	25	11,500	7,300	11,200	7,800	9,600	60	100
25	Nutmeg hickory	72	12,300	6,400	11,000	7,100	8,800	79	97
26	Pecan hickory	37	10,500	5,800	10,400	7,300	9,100	51	95
27	Pignut hickory	30	13,000	8,700	12,700	8,900	10,900	72	100
28	White elm	18	8,800	4,900	8,800	5,000	6,500	28	88
29	Cedar elm	44	10,600	6,200	10,100	6,500	8,000	66	95
30	White ash	87	9,600	5,000	8,700	5,700	7,200	48	96
31	Green ash	10	9,800	6,600	9,800	6,600	8,000	29	100
32	Sweet gum	118	8,900	4,600	8,500	5,600	7,100	60	97

a Actual tests on "dry" material not reduced for moisture.

The variation in strength in wood of the virgin forest, as will be seen from the tables, is in some species so great that by proper inspection and selection values differing by 25 to 50 per cent may be obtained from different parts of the same tree, and values differing 100 to 200 per cent within the same species. These differences have all their definite recognizable causes, to find and formulate which is the final aim of these investigations.

The tests are intentionally not made on selected material (except to discard absolutely defective pieces), but on material as it comes from the trees, so as to arrive at an average statement for the species, when a sufficient number of trees has been tested. How urgent is the need for data of inspection as above indicated will appear from the wide range of results recorded.

To enable any engineer to use the data here given with due caution and judgment, not only the ranges of values and the average of all values obtained, but also the proportion of tests which came near the average values, have been stated, as well as the average results of the highest and lowest values of 10 per cent of the tests. With this information and a statement of the actual number of tests involved, the comparative merit of the stated values can be judged. With a large number of tests, to be sure, it is more likely that an average value of the species has been found. The actual test results have been rounded off to even hundreds in the tables.

FACTORS OF SAFETY.

With such lowest standard values, also lowest factors of safety could be employed. As to factors of safety, it may be proper to state that the final aims of the present investigations may be summed up in one proposition, namely, to establish rational factors of safety. It will be admitted by all engineers that the factors of safety as used at present can hardly be claimed to be more than guesswork. There is not an engineer who could give account as to the basis upon which numerically the factors of safety for wood have been established as "8 for steady stress; 10 for varying stress; 15 for shocks" (see Merriman's Textbook on the Mechanics of Materials); or as 4 to 5 for "dead" load and 5 to 10 for "live" load (see Rankine's Handbook of Civil Engineering).

The directions for using these indeterminate factors of safety given in the text-books would imply that the student or engineer is, after all, to rely on his judgment as to the modification of the factor, i. e., he is to add to this general guess his own particular guess. The factor of safety is in the main an expression of ignorance or lack of confidence in the reliability of values of strength, upon which the designing proceeds, together with an absence of data upon which to inspect the material. With a larger number of well-conducted tests, coupled with a knowledge of the quantitative as well as qualitative influences of various factors upon strength, and with definite data of inspection which allow ready sorting of material, the factor of safety, as far as it denotes the residuum of ignorance which may be assumed to remain, as to the character and behavior of the material, may be reduced to a minimum, restricting itself mainly to the consideration of the indeterminable variation in the actual and legitimate application of load.

Results of tests in compression endwise on green wood (above 40 per cent moisture, not reduced).

[Pounds per square inch.]

No.	Species.	Number of tests.	Highest single test.	Lowest single test.	Average of all tests.
1	Longleaf pine	86	7, 300	2, 800	4, 300
2	Cuban pine	38	6, 100	3, 500	4, 800
3	Shortleaf pine	8	4, 000	3, 000	3, 300
4	Loblolly pine	69	5, 500	2, 600	4, 100
7	Spruce pine	71	4, 700	2, 800	3, 900
8	Bald cypress	280	8, 200	1, 800	4, 200
9	White cedar	34	3, 400	2, 300	2, 900
11	White oak	25	7, 000	3, 200	5, 300
12	Overcup oak	45	4, 900	2, 800	3, 800
14	Cow oak	58	4, 900	2, 300	3, 800
16	Texan oak	39	6, 000	3, 100	5, 200
19	Willow oak	49	5, 500	2, 300	3, 800
20	Spanish oak	52	5, 100	2, 500	3, 900
21	Shagbark hickory	22	6, 900	3, 500	5, 700
22	Mockernut hickory	18	7, 200	4, 500	6, 100
23	Water hickory	4	5, 600	4, 700	5, 200
25	Nutmeg hickory	26	5, 500	3, 700	4, 500
26	Pecan hickory	4	3, 800	3, 300	3, 600
27	Pignut hickory	5	6, 200	4, 700	5, 400
32	Sweet gum	6	3, 600	3, 000	3, 300

While the values given in these tables may claim to contain more elements of reliability than most of those published hitherto, much more work will have to be done before the above-stated aim will be satisfied.

In explanation of the table recording tests in bending at relative elastic limits it should be stated that since an elastic limit in the sense in which the term is used for metals, namely, as a point at which distortion becomes disproportionate to load and a permanent injury and set results, can not be readily determined for wood, Prof. J. B. Johnson has proposed to utilize a point where the rate of distortion becomes 50 per cent greater for the amount of load than it was for the initial load, which point can be tolerably accurately determined (see Bull. 8, p. 9). This point he has called the "relative elastic limit." The assumption is that such a point would be near the limit to which the material can be strained without permanent injury, and the strength values obtained at that point would serve for indications of safe loads.

The practical utility of determining this point and the strength values relating to it remains, however, still open for discussion. A comparison of the values obtained for the strength at rupture and at relative elastic limit shows a parallelism which would make it questionable whether much is gained by the use of that point, which in reality lies beyond the limit where practical injury has begun, as indicated by the increased distortion.

We would be inclined to consider that point more serviceable where the curve begins to deviate from the straight line, at which point we may assume no permanent injury has as yet been experienced. This point we may call provisionally the "safe limit."

Objection has been made to utilizing this point because it can not be located with as much nicety and mathematical precision as the point of "relative elastic limit." But even this point is only approximately definable; and since no strength values can claim to be more than approximately correct, it would suffice to determine the safe-limit point and the correspondent strength values also only approximately. This point has the advantage that it lies on the safe side.

Special series of tests to investigate the legitimacy of the use of any of these limits for practical purposes were designed, but have as yet not been taken up, and hence the values in the table on p. 367 are given only as suggestions for what they are worth.

Results of tests in bending, at rupture.

[Pounds per square inch.]

No.	Species.	Number of tests.	Highest single test.	Lowest single test.	Average highest 10 per cent of tests.	Average lowest 10 per cent of tests.	Average of all tests.	Proportion of tests within 10 per cent of average.	Proportion of tests within 25 per cent of average.
	Reduced to 15 per cent moisture.							*Per cent.*	*Per cent.*
1	Longleaf pine	1,160	17,800	3,300	14,200	8,800	10,900	41	84
2	Cuban pine	390	17,000	2,900	14,600	8,800	11,900	46	83
3	Shortleaf pine	330	15,300	5,000	12,400	7,000	9,200	40	79
4	Loblolly pine	650	14,800	3,900	13,100	8,100	10,100	44	84
	Reduced to 12 per cent moisture.								
5	White pine	120	11,100	4,600	10,100	5,000	7,900	43	81
6	Red pine	95	12,900	3,100	12,300	4,900	9,100	28	60
7	Spruce pine	170	16,300	3,100	13,600	5,800	10,000	43	81
8	Bald cypress	655	14,800	2,300	11,700	5,000	7,900	25	69
9	White cedar	87	9,100	3,500	8,400	4,000	6,300	32	78
10	Douglas spruce *a*	41	13,000	3,800	12,000	4,100	7,900	22	58
11	White oak	218	20,300	5,700	18,500	7,600	13,100	39	75
12	Overcup oak	216	19,600	4,900	14,900	6,300	11,300	47	81
13	Post oak	49	16,400	5,100	15,300	7,400	12,300	47	92
14	Cow oak	256	23,000	3,300	12,500	6,500	11,500	32	68
15	Red oak	57	16,500	5,700	15,400	9,100	11,400	46	84
16	Texan oak	117	19,500	8,200	16,900	10,000	13,100	64	86
17	Yellow oak	40	15,000	5,100	14,600	5,700	10,800	28	65
18	Water oak	31	16,000	5,800	15,700	7,200	12,400	40	76
19	Willow oak	153	16,000	3,200	13,800	5,400	10,400	33	70
20	Spanish oak	257	17,300	5,000	15,600	6,900	12,000	40	72
21	Shagbark hickory	187	23,300	5,700	20,300	9,400	16,000	46	84
22	Mockernut hickory	75	20,700	5,300	19,700	7,900	15,200	45	78
23	Water hickory	14	18,000	5,300	17,300	5,400	12,500	21	64
24	Bitternut hickory	25	19,500	7,000	19,300	8,700	15,000	28	60
25	Nutmeg hickory	72	16,600	6,700	15,600	8,100	12,500	40	88
26	Pecan hickory	37	18,300	5,600	18,100	10,300	15,300	38	95
27	Pignut hickory	30	25,000	11,100	24,300	11,500	18,700	43	77
28	White elm	18	14,000	7,300	13,600	7,300	10,300	44	72
29	Cedar elm	44	19,200	6,600	17,300	8,500	13,500	50	86
30	White ash	87	15,000	5,000	14,200	6,300	10,800	37	77
31	Green ash	10	16,000	5,100	16,000	5,100	11,600	20	60
32	Sweet gum	118	14,400	5,100	12,700	6,000	9,500	39	79

a Actual tests on "dry" material not reduced for moisture.

RELATIONS OF WEIGHT AND STRENGTH.

That within the same species the strength of wood varied with the dry weight (specific gravity), i. e., that the heavier stick is the stronger, has been known for some time. That this law of variation held good not only for a given species, but irrespective of species for the four principal pines of our Southern States was indicated in Circular 12 of this Division. This fact becomes the more important in practical application, as the wood of these species of pines so far can not be distinguished at all by its anatomical structure and only with difficulty and uncertainty by other appearances, while in the lumber market substitution is not infrequent. It will therefore be best with these pines, where strength alone is desired, to inspect the material by weight (specific), other things being equal, disregarding species determination.

While this result of the exhaustive series of tests reasonably well demonstrated for these pines may be considered of great practical value, we can now extend the application of the law of relation between weight and strength a step farther, and state as an indication of our tests that probably in woods of uniform structure strength increases with specific weight, independently of species and genus distinction, i. e., other things being equal, the heavier wood is the stronger. We are at present inclined to state this important result with caution, only as a probability or indication, until either the test material and tests can be more closely scanned, or more carefully planned and minutely executed series of detail tests can be carried on to confirm the truth of what the wholesale tests seem to have developed.

In the following two diagrams the average strength of the different species in compression endwise and bending, as found in the preceding tables, has been plotted with reference to the dry weight as given in preceding table.

Considering that these tests and weight determinations (especially the latter) were not carried on with that finesse which would be required for a scientific demonstration of a natural law, that other influences, as crossgrain, unknown defects, and moisture conditions may cloud the results, and that in the averaging of results undue consideration may have been given to weaker or stronger, heavier or lighter, material, the relaxation is exhibited even by this wholesale method with a remarkable degree of uniformity bordering on demonstration.

An exception is apparent in the oaks in that they do not exhibit this relation of weight and strength with reference to other species, and also with less definiteness among the various species of oak in themselves. The structure of oak wood being exceedingly complicated and essentially different from that of the wood of all other species under consideration, it may reasonably be expected that it will not range itself with these.

Results of tests in bending, at relative elastic limit.

[Pounds per square inch.]

No	Species.	Number of tests.	Highest single test.	Lowest single test.	Average of highest 10 per cent of tests.	Average of lowest 10 per cent of tests.	Average of all tests.	Proportion of tests within 10 per cent of average.	Proportion of tests within 25 per cent of average.	Modulus of elasticity (average of all tests).
	Reduced to 15 per cent moisture.							*Per cent.*	*Per cent.*	
1	Longleaf pine	1,160	13,500	2,400	11,100	5,400	8,500	43	81	1,890,000
2	Cuban pine	390	12,900	2,200	11,500	5,600	9,500	42	83	2,300,000
3	Shortleaf pine	330	11,900	2,900	9,700	4,800	7,200	48	81	1,600,000
4	Loblolly pine	650	12,700	3,100	10,800	5,400	8,200	46	85	1,950,000
	Reduced to 12 per cent moisture.									
5	White pine	130	10,000	4,100	8,200	4,500	6,400	58	85	1,390,000
6	Red pine	95	11,300	3,100	10,300	4,500	7,700	38	73	1,620,000
7	Spruce pine	170	13,700	3,000	11,200	5,000	8,400	51	82	1,640,000
8	Bald cypress	655	12,000	2,200	9,900	4,200	6,600	25	66	1,290,000
9	White cedar	87	8,200	3,400	7,390	4,000	5,800	44	86	910,000
10	Douglas spruce *a*	41	13,700	2,800	9,600	3,400	6,400	32	56	1,680,000
11	White oak	218	15,700	4,400	14,100	6,100	9,600	37	73	2,090,000
12	Overcup oak	216	11,600	4,000	9,500	5,400	7,500	47	91	1,620,000
13	Post oak	49	10,600	5,100	9,600	6,000	8,400	34	76	2,030,000
14	Cow oak	256	14,200	3,400	11,600	5,000	7,600	50	95	1,610,000
15	Red oak	57	14,500	5,100	13,600	5,600	9,200	15	49	1,970,000
16	Texan oak	117	12,600	5,900	11,400	7,800	9,400	62	94	1,860,000
17	Yellow oak	40	11,800	4,900	11,100	5,100	8,100	35	75	1,740,000
18	Water oak	31	11,800	4,500	11,400	5,500	8,800	40	84	2,000,000
19	Willow oak	153	13,100	2,700	10,000	4,300	7,400	42	81	1,750,000
20	Spanish oak	257	13,500	5,100	11,600	6,600	8,600	41	80	1,930,000
21	Shagbark hickory	187	16,100	5,400	14,200	7,700	11,200	50	89	2,390,000
22	Mockernut hickory	75	15,400	4,300	14,600	7,800	11,700	39	83	2,320,000
23	Water hickory	14	11,900	4,100	11,800	4,800	9,800	21	86	2,080,000
24	Bitternut hickory	25	14,300	7,500	14,000	7,600	11,100	44	84	2,280,000
25	Nutmeg hickory	72	12,200	4,200	11,200	6,400	9,300	46	93	1,940,000
26	Pecan hickory	37	15,000	5,800	14,400	7,900	11,500	65	89	2,530,900
27	Pignut hickory	30	17,500	7,400	16,400	8,300	12,600	40	83	2,730,000
28	White elm	18	9,700	5,300	9,600	5,400	7,300	33	71	1,540,000
29	Cedar elm	44	10,700	4,700	10,100	5,800	8,000	57	91	1,700,000
30	White ash	87	14,500	3,600	10,400	5,200	7,900	43	83	1,640,000
31	Green ash	10	13,200	3,200	13,200	3,200	8,900	40	70	2,050,000
32	Sweet gum	118	11,000	3,500	10,100	5,100	7,800	46	82	1,700,000

a Actual tests on "dry" material not reduced for moisture.

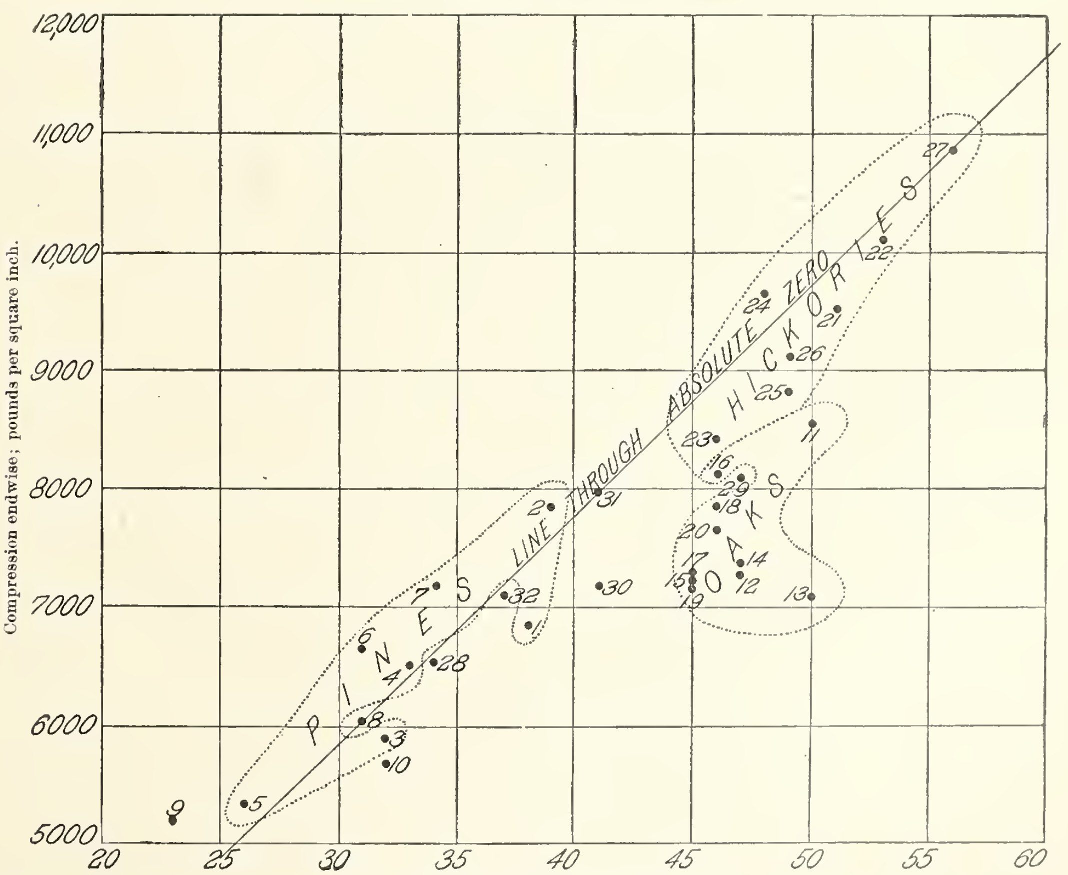


Fig. 95.—Relation of strength in compression endwise to weight of material. The figure at each point indicates the species thereby represented.

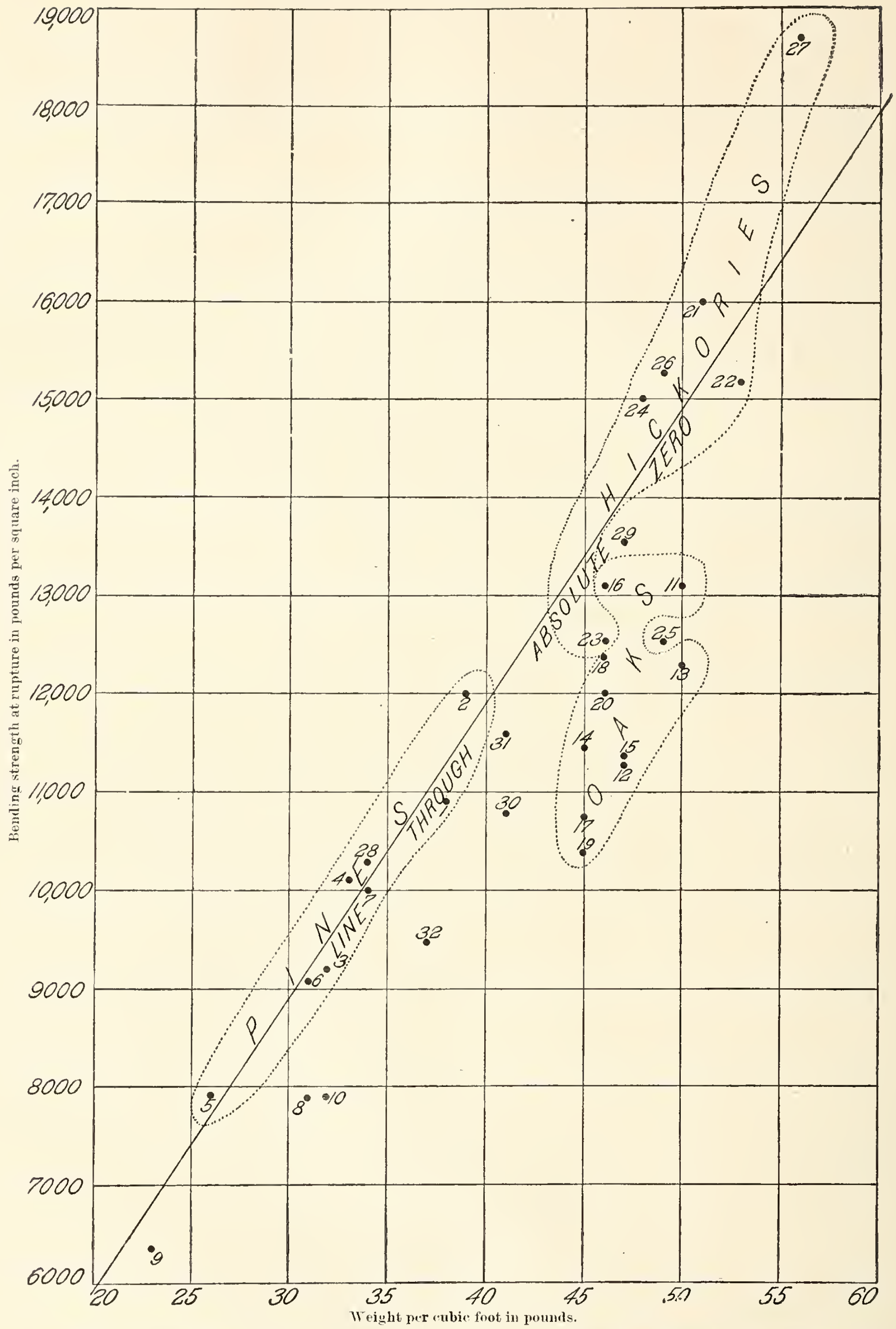


FIG. 96.—Relation of weight to bending strength at rupture. The figure at each point indicates the species thereby represented.

In addition, the difficulty of seasoning oak without defects or even securing perfect material may have influenced the results of tests so as to cloud the relationship with the genus.

If further close study, supplemented by additional series of tests carefully devised to investigate this relationship, should uphold the truth of it, this result may be set down as the most important practical one that could be reached by these tests, for it would at once give into the hands of the wood consumer a means of determining the relative value of his material as to strength and all allied properties by a simple process of weighing the dry material; of course with due regard to the other disturbing factors like crossgrain, defects, coarseness of grain, etc.

Results of tests in compression across grain (a) and shearing with grain.

[Pounds per square inch.]

No.	Species.	Number of tests.	Compression across grain.	Shearing with grain not reduced for moisture.
	Reduced to 15 per cent moisture.			
1	Longleaf pine	1,210	1,000	700
2	Cuban pine	400	1,000	700
3	Shortleaf pine	330	900	700
4	Loblolly pine	690	1,000	700
	Reduced to 12 per cent moisture.			
5	White pine	130	700	400
6	Red pine	100	1,000	500
7	Spruce pine	175	1,200	800
8	Bald cypress	650	800	500
9	White cedar	87	700	400
10	Douglas spruce b	41	800	500
11	White oak	218	2,200	1,000
12	Overcup oak	216	1,900	1,000
13	Post oak	49	3,000	1,100
14	Cow oak	256	1,900	900
15	Red oak	57	2,300	1,100
	Reduced to 12 per cent moisture—Continued.			
16	Southern red oak	117	2,000	900
17	Black oak	40	1,800	1,100
18	Water oak	30	2,000	1,100
19	Willow oak	153	1,600	900
20	Spanish oak	255	1,800	900
21	Shagback hickory	135	2,700	1,100
22	White hickory	75	3,100	1,100
23	Water hickory	14	2,400	1,000
24	Bitternut hickory	25	2,200	1,000
25	Nutmeg hickory	72	2,700	1,100
26	Pecan hickory	37	2,800	1,200
27	Pignut hickory	30	3,200	1,200
28	White elm	18	1,200	800
29	Cedar elm	44	2,100	1,300
30	White ash	87	1,900	1,100
31	Green ash	10	1,700	1,000
32	Sweet gum	118	1,400	800

a To an indentation of 3 per cent of the height of the specimen.

b Actual tests on "dry" material not reduced for moisture.

Having fully established the great influence of moisture on the strength of wood, the practitioner still needed information as to the rate and manner of drying and as to the way in which moisture is distributed during seasoning. Several thousand moisture determinations were made and it was established beyond doubt that moisture is generally least abundant at the ends, is quite evenly distributed throughout the length, but is not always uniform in different parts of the same cross section, often varying in this respect within astonishing ranges, so that the use of timber in a half-seasoned condition, and where uniform seasoning can not be obtained by the material, requires that these facts be duly considered in designing.

Tests of Maximum Uniformity.

Both in this country and abroad small differences in strength values were often interpreted as deciding for or against any given material. This same problem arose also in every case where many results were to be compiled, and it seemed especially desirable once for all to find just how much uniformity could be expected of wood materials. From a large series of well-selected quarter-sawed pieces representing several kinds of pine, cypress, and hardwoods it was found that even contiguous blocks, 2½ inches long, may differ by as much as 2 to 4 per cent in conifers and as much as 13 per cent in oak, and that in a scantling only 6 feet long the butt might differ from the top by 10 to 20 per cent in conifers and over 35 per cent in oak. This extremely valuable set of results throws much light upon discussions of the past, and is well suited to show that many boastful claims rested on very flimsy and entirely unreliable differences, such as might well be accounted for by a little more extended examination of materials. It will also assist in judging test results in the future and help to avoid useless controversy and prejudice. The following more fully illustrates the results of this series:

Scantlings of air-dry material, 6 to 10 feet long, of white pine, longleaf pine, tuliptree (poplar), and white oak, and of perfectly green material of loblolly pine and cypress, fresh from the saw, were cut partly into blocks 2 by 2 by 2¾ inches, but mostly into cubes of 2¾ inches. All material was quarter sawed, carefully prepared, and in all cases treated alike, either perfectly green or dried together at the same temperature. Altogether 529 tests in endwise compression were made, namely, 100 on white pine, 72 on longleaf pine, 99 on loblolly pine, 40 on white oak, 115 on tuliptree (poplar), 103 on cypress.

From these tests the following table of averages is derived, together with fig. 97:

Average of tests for maximum uniformity.

Name.	Moisture.	Average strength of all pieces.	Greatest difference in strength between adjoining pieces.		Greatest difference in entire scantling, i. e., 6–10 foot piece.
	Per cent.	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Per cent.*	*Per cent.*
White pine (Pinus strobus)	8	4,900	190	3.8	18
Longleaf pine (Pinus palustris)	7.8	10,800	380	3.5	10
Tuliptree (poplar) (Liriodendron tulipifera)	8	6,010	480	8.3	20
White oak (Quercus alba)	Yard dry.	8,300	1,110	13.4	37
Loblolly pine (Pinus tæda)	125 + (green).	2,670	130	4.8	20
Cypress (Taxodium distichum)	125 + (green).	4,090	70	1.8	15

It will be observed that green cypress excelled in its uniformity; that green loblolly proves not more uniform than dry white and longleaf pine; that wood of the conifers far excel even the tuliptree (poplar) with its uniform grain and texture; and that oak, as might be expected, is the least uniform. It will also be noticed that even in one and the same short scantling (6 to 10 feet) of select quarter-sawed longleaf pine differences of 10 per cent may occur, and that in all others these differences were even greater.

Incidentally in this and the following experiment a small number of the blocks were thoroughly oven-dried (to about 2 per cent moisture), and it was found that the strength of both cypress and loblolly was increased by about 150 per cent during drying, so that wood at 2 per cent is about two and one-half times as strong as perfectly green or soaked material; and also that drying from 8 to 10 per cent to the lowest attainable moisture condition (1 to 2 per cent) still adds about 25 per cent to the strength of the wood.

In the following diagram and table a part of the results are presented in detail:

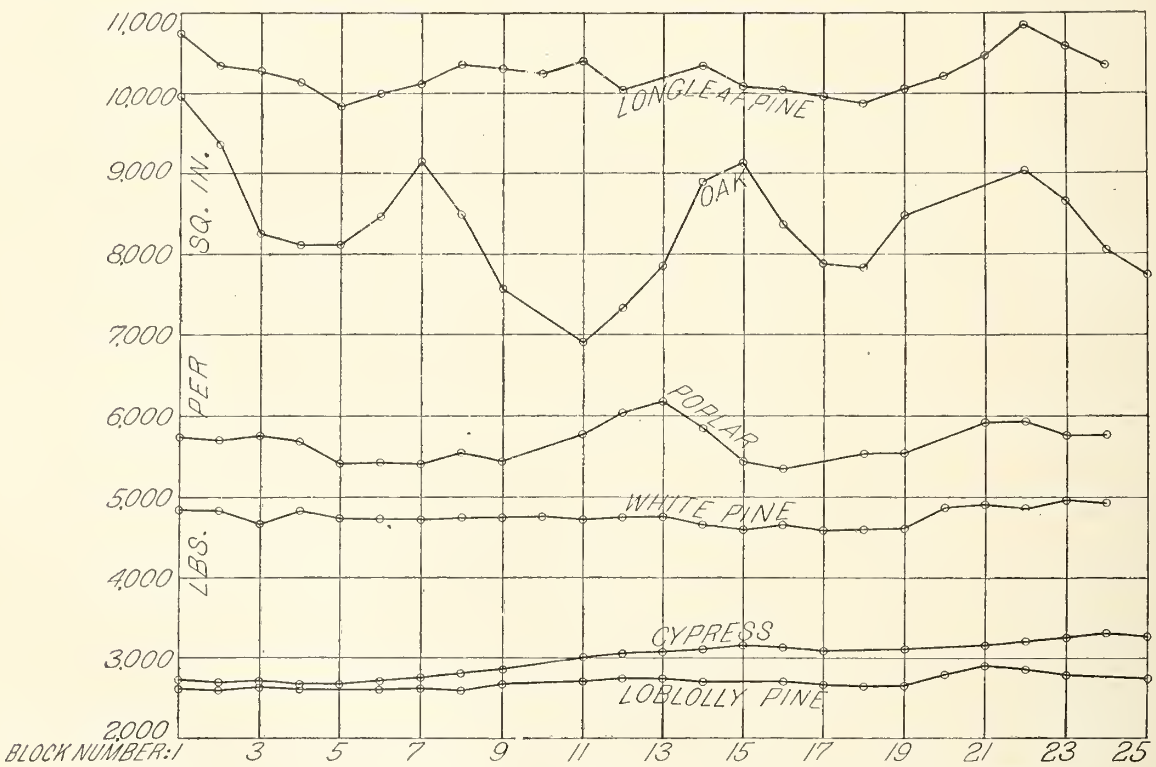


FIG. 97.—Strength of contiguous blocks, showing maximum uniformity of select quarter-sawed material in compression endwise.

Strength of contiguous blocks of the same scantling, select material, in compression endwise.

[Dimensions generally, 2.76 by 2.76 by 2.76 inches.]

Number of blocks.	Kind of wood.						
	White pine (8 per cent moisture).	Longleaf pine (8 per cent moisture).	Loblolly pine (125+per cent moisture).	Cypress (125+per cent moisture).		Tulip-tree (8 per cent moisture).	Oak (yard dry).
	Pounds per square inch.						
1	4,850	11,580	2,330	2,720	4,170	5,740	9,970
2	4,860	11,530	2,380	2,700	4,190	5,700	9,370
3	4,690	11,310	2,380	2,720	4,170	5,770	8,260
4	4,840	11,060	2,450	2,680	4,180	5,700	8,120
5	4,760	8,250	*a* 5,700	2,680	4,200	5,430	8,120
6	4,720	10,740	2,600	2,720	4,180	5,430	8,480
7	4,730	11,180	2,680	2,770	4,230	5,420	9,150
8	4,760	11,220	2,640	2,820	....	5,560	8,500
9	4,750	10,980	2,720	2,870	....	5,440	7,580
10	4,770	11,130	*a* 6,970	....	....	*a* 7,070	....
11	4,730	11,510	2,770	3,020	4,230	5,770	6,910
12	4,760	11,490	2,730	3,070	4,180	6,030	7,340
13	4,770	11,320	2,780	3,099	4,130	6,170	7,870
14	4,670	11,220	2,800	3,120	4,160	5,840	8,900
15	4,600	11,320	*a* 5,840	3,170	4,160	5,440	9,130
16	4,660	11,340	2,880	3,140	4,160	5,360	8,380
17	4,590	11,470	2,870	3,090	4,110	....	7,890
18	4,600	10,790	2,870	....	4,090	5,530	7,840
19	4,610	10,740	2,860	3,120	4,070	5,530	8,480
20	4,880	11,030	*a* 6,480	....	....	*a* 6,880	....
21	4,920	11,110	2,760	3,170	....	5,920	....
22	4,870	11,450	2,760	3,220	....	5,930	9,030
23	4,970	12,250	2,720	3,270	....	5,770	8,660
24	4,940	12,760	2,640	3,320	....	5,780	8,060
25	....	10,740	*a* 7,050	3,270	....	6,120	7,740
26	5,070	10,350	2,680	....	....	6,480	7,580
27	4,940	10,280	2,650	3,320	....	6,310	8,400
28	5,020	10,150	2,650	3,370	....	6,220	8,710
29	5,110	9,860	2,780	3,420	....	6,310	8,060
30	5,020	10,000	*a* 7,320	....	....	*a* 7,420	....
31	4,950	10,120	2,730	3,490	....	6,340	7,280
32	4,820	10,370	2,780	3,520	....	6,360	7,510
33	4,950	10,320	2,720	3,570	....	6,040	7,510
34	4,900	10,250	2,660	3,620	....	....	8,080
35	5,040	10,400	*a* 5,360	3,640	....	6,280	9,030
36	5,160	10,050	2,610	....	....	6,490	8,790
37	5,120	10,050	2,560	....	....	6,610	8,640
38	5,100	10,350	2,580	....	....	6,220	8,560
39	5,230	10,100	2,580	....	....	6,190	8,780
40	5,280	10,030	*a* 5,220	....	....	*a* 7,300	....
41	5,260	9,970	2,620	....	....	6,010	....
42	5,280	9,880	2,600	....	....	6,140	....
43	5,300	10,050	2,640	....	....	6,170	....
44	5,310	10,220	2,610	....	....	6,010	....
45	5,300	10,470	*a* 6,440	....	....	6,490	....
46	5,350	10,860	2,620	....	....	....	....
47	5,400	10,590	2,620	....	....	6,080	....
48	5,360	10,350	2,600	....	....	5,860	....
49	5,360	11,150	2,680	....	....	6,110	....
50	5,510	10,970	*a* 6,440	....	....	*a* 7,920	....
51	5,070	10,890	2,710	....	....	6,210	....
52	5,150	10,790	2,750	....	....	6,270	....
53	5,020	10,970	2,760	....	....	6,300	....
54	4,770	11,040	2,720	....	....	6,420	....
55	4,770	10,940	*a* 6,850	....	....	6,450	....
56	4,920	10,970	2,710	....	....	6,170	....
57	4,950	10,840	2,680	....	....	6,440	....
58	4,840	10,710	2,660	....	....	6,340	....
59	4,860	10,890	2,660	....	....	6,310	....
60	*a* 6,460	10,710	*a* 7,030	....	....	*a* 7,540	....

a Dried to about 2 per cent moisture before testing.

As was indicated at the outset and is fully explained in Bulletins 6 and 8, the plan of this investigation also included among the objects to be sought the establishment of the following:

(1) The relative value of each species.

(2) The outward signs or physical and structural properties. easily used in inspection.

(3) The relation of the properties among themselves; and

(4) Their relation to the conditions under which the wood is formed, such, for instance, as the age of the tree when wood is laid on, influences of soil, climate, etc.

As has been explained, some of these relations were more or less fully determined, at least, qualitatively; nevertheless, the relation of the several forms of resistance, as well as the mutual relations of the properties in general, seemed to escape observation in the manner of inquiry generally pursued. It became clear before long that these laws must be established by special series, planned each to seek answer to some specific question. Several of these were carried out,

and, though little more was accomplished than to find proper ways, the study of these results, amplified by the large ordinary series, led to several interesting discoveries, the most important of which is the discovery of the relation between the strength in cross bending at elastic limit and the compression endwise, this latter being equal to the fiber stress of the former. Though still requiring special experiments to become convincing, it is fair to state at this point that a great deal of useless testing will be saved in the future, since the test in compression is by all means the simplest, the selection and treatment of the material for it the easiest, and the result the most satisfactory. The importance of this discovery by Mr. S. T. Neely is such that a reprint of Mr. Neely's discussion here will be found justified.

Relation of Compression-endwise Strength to Breaking Load of Beam.

In testing timber to obtain its various coefficients of strength, the test which is at once the simplest, most expedient, satisfactory, and reliable is the "compression-endwise test," which is made by crushing a specimen parallel to the fibers. All other tests are either mechanically less easily performed, or else, as in the case of cross-bending, the stresses are complex, and the unit coefficient can be expressed only by reliance upon a theoretical formula, the correctness of which is in doubt. It would, therefore, be of great practical value to find a relation between the cross-bending strength, the most important coefficient for the practitioner, and the compression strength, when the study of wood would not only be greatly simplified and cheapened, but the data could be applied with much greater satisfaction and safety.

The consideration of such a relation resolves itself naturally into two parts, namely, a study of the relation of the internal stresses in a beam to the external load which produces them, and a study of the relation of the internal stresses in a beam to the compression-endwise strength of the material of which the beam is made.

The first relation has been a subject of study for more than two centuries, and from the time of Galileo down to the present day the theory of beams has been gradually evolved. Within recent years several eminent physicists and engineers have given a true analysis of both the elastic and ultimate strength of a beam, a clear exposition of which is made by Prof. J. B. Johnson in his work on Modern Framed Structures. He points out that the "ordinary equation" for obtaining the extreme fiber stresses, when the external load and dimensions of the beam are given, is not applicable to a beam strained beyond its elastic limit; and he follows this statement with a discussion of the true distribution of internal stresses in a beam at time of rupture, and with a "Rational equation for the moment of resistance at rupture," devised by M. Saint-Venant, which really does connect the extreme fiber stress in a bent beam with the compression-endwise strength and also with the tension strength. Professor Johnson's final conclusion, however, is that for practical use the "ordinary formula" may be applied to a beam at rupture, providing the fiber stress involved is obtained from cross-bending tests; and this is the present practice among engineers.

RELATION OF INTERNAL STRESSES.

Assume for the discussion of the relation of internal stresses to external load the simple conditions of a beam of rectangular cross section loaded at the middle.

Regarding the distribution of internal stresses, it must be agreed that the neutral plane lies in the center of the beam so long as the beam is loaded within the elastic limit; this follows from the fact that the modulus of elasticity is the same whether derived from compression tests or from tension tests (i. e., $E_c = E_t$), as proved by experiments of Nördlinger, Bauschinger, Tetmayer, and others.

Since the distortion of any given fiber in the beam is proportional to its distance from the neutral plano, the distribution of stresses in a longitudinal section of a beam loaded up to its elastic limit may be represented by the following diagram, in which the vertical scale represents increments of distortion and the horizontal scale the fiber stresses.

In this diagram the angle a = angle b, since $E_c = E_t$; and furthermore, since these latter quantities are each equal to the modulus of elasticity obtained from cross-bending tests (according to the same authorities), this angle a (or b) can be obtained by platting the results of the cross-bending test itself.

It is a well-established fact that the tension strength of wood is much greater than the compression strength, and also, as shown by the German experimenters quoted, that the elastic limit in either case is not reached until shortly before the ultimate strength. Furthermore, it seems reasonable to suppose, and is essential to the construction of the above diagram, that the true elastic limit of the beam (shown on the strain diagram of a beam at the point where it ceases to be a straight line) is reached at the same instant that the elastic limit of the extreme compression fiber is reached; for when the loading is continued beyond this latter condition the line OC must begin to curve upward (since the proportion of load to distortion on that side begins to increase more rapidly), while the line OT continues in its original direction. Therefore, in order to maintain the equilibrium, the whole distribution of stresses will necessarily be changed, the position of the neutral axis will be lowered, and these changes will, of course, show an effect on the deflection of the beam.

Now, even at rupture the proportionality of fiber distortion to distance from neutral axis is maintained (because a plane cross section will always remain a plane), and therefore the distribution of internal stresses just at the point of rupture can be represented by a diagram similar to fig. 99, in which, as before, the vertical scale represents increments of distortion and the horizontal scale fiber stresses. The fibers on either side of the neutral plane are under stresses which vary from zero at the neutral plane to the maximum stress in the extreme fiber, changing in proportion

as the increments of load in the test machine vary. Therefore, the distribution of stresses on the compression side of the neutral plane will be shown by an ordinary strain diagram for compression, and on the tension side by a similar tension-strain diagram. Unfortunately there are no reliable diagrams of these kinds now on record. The compression pieces tested have usually been too short to afford reliable measurements of distortion, and, owing to structural and mechanical difficulties, satisfactory tension tests seem to be impossible.

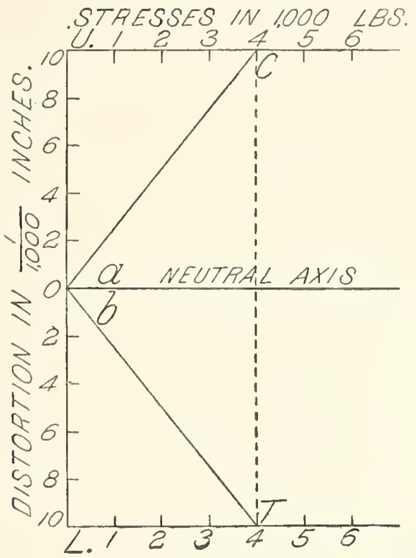


FIG. 98.—Relation of fiber stresses and distortions.

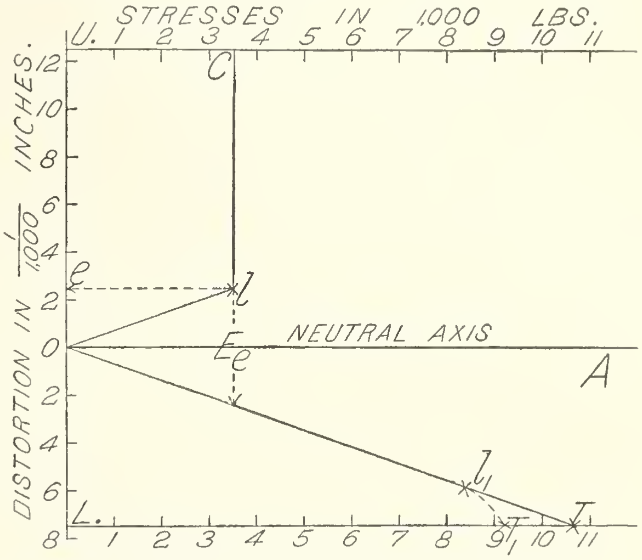


FIG. 99.—Distribution of internal stresses in a beam at rupture.

Experience in testing, however, has taught that when a piece of green wood is tested in compression it will undergo a great distortion after the maximum load has been applied without actually breaking down—in fact, while sustaining the same load. A piece tested in tension, on the other hand, breaks suddenly as soon as the maximum load is applied. A beam in failing may, therefore, sustain an increasing load long after the extreme compression fiber has been loaded to its ultimate strength; the fibers on the compression side continue to be mashed down, while the neutral plane is lowered and the stress in the tension fiber increases until, very often in practice, the beam "fails in tension." With these facts and observations before us it is possible to construct a diagram so that it will represent, approximately, at least, the distribution of internal stresses in a beam at rupture. (See fig. 100.)

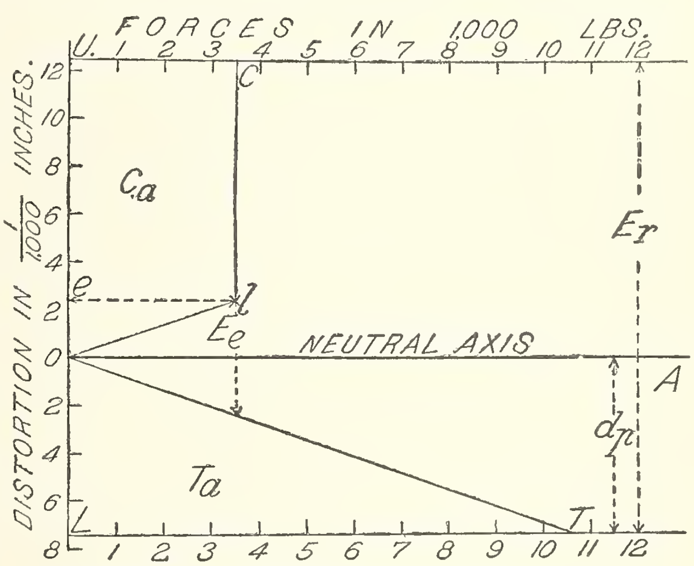


FIG. 100.—Position of neutral axis and internal stresses at rupture of beam.

In this figure OA represents the position of neutral plane at time of rupture, OU the distortion in the extreme compression fiber, UC the stress on same fiber, OL the distortion in extreme tension fiber, and LT the stress on that fiber.

It can readily be seen that the manner of breaking will influence slightly the form of this diagram. If the beam fails in compression before the tension fiber reaches its elastic limit the line OT will be straight as shown, otherwise the line will assume some such position as Ol_1T_1 (diagram 99), in which l_1 is the elastic limit in tension.

From the approximate distribution of internal stresses their relation to the external load may be determined. The two fundamental equations—(1) that the sum of internal stresses on the tension side equals the sum of internal stresses on the compression side, and (2) that the sum of the external moments equals the sum of the internal moments—apply at the time of rupture as well as at the elastic limit. From (1) it follows that area $OUCl =$ area OLT, and the position of the neutral plane at rupture is thereby fixed. If now the line LU be assumed to represent the depth of the beam in inches instead of indicating the distortion of the fibers, the sum of the internal moments about the point O is found by multiplying the area of either the compression or tension diagram by the sum of the distances of their respective centers of gravity from the neutral plane. By putting this sum equal to the moment of the external load about the same point O the first relation is established.

RELATION OF CRUSHING-ENDWISE STRENGTH.

The second relation (that of crushing-endwise strength to internal stresses) was touched upon in discussing the first, when it was stated: (1) That the true elastic limit of the beam is probably reached at the same instant that the extreme fibers on the compression side reach their elastic limit in compression. (2) That this latter limit lies close to the ultimate compression-endwise strength (so close that former experimenters have been unable satisfactorily to separate them). (3) That a piece of green wood will stand a great deal of distortion after the ultimate load is applied before actually failing. And to these statements may be added the evident fact (4) that the stress on any fiber on the compression side can not exceed the compression-endwise strength of the material. (5) Finally and most important it appears from (1) and (2), but especially from an examination of the several thousand test results on the several species of conifers made by the Division of Forestry, that the extreme fiber stress at the true elastic limit of a beam is practically identical with the compression-endwise strength of the material. (This last observation, which was forced upon the writer by its continual repetition in the large series of tests under review, lies at the basis of this discussion.) The observation of this identity makes the distribution of internal stresses appear more simple than was hitherto assumed, and the desired relation between compression and cross-bending strength capable of mathematical expression.

DEVELOPMENT OF FORMULÆ.

From these considerations the distance UC in fig. 100, which represents the ultimate compression-endwise strength of the material, becomes practically equal to the distance *el*, which represents the compression strength at the true elastic limit, and hence the line lC straight and vertical; and if OT is taken as straight, the diagram will be made up of simple geometric figures, as in fig. 100.

The line LU will represent the total fiber distortion at time of rupture, and is equal to the sum of the amounts by which the extreme compression fibers shorten and the extreme tension fibers elongate.

Let a test in which the following quantities have been observed and recorded be considered:

Let P_r = the external load at rupture (pounds).
Δ_r = the corresponding deflection of the beam (inches).
C = compression-endwise strength of the material (pounds).
E = modulus of elasticity (pounds).
d = depth of beam (inches).
b = breadth of beam (inches).
l = length of beam (inches).
Δ_e = deflection at true elastic limit.

Then, based upon the above statements, by means of formulas derived from the geometric relations of the diagram and the fundamental equations of equilibrium, the following quantities can be calculated:

Let E_e = total fiber distortion due to bending at true elastic limit (inches).
E_r = total fiber distortion due to bending at rupture = LU (inches).
d_p = distortion in extreme tension fiber at rupture = LO (inches); also the proportional distance of neutral plane from tension side of beam.
d_r = real distance of neutral plane at rupture from tension side of beam (inches).
d_e = real distance of neutral plane at rupture from that fiber on compression side which has just reached the elastic limit, in inches = Oe.
T = stress in extreme tension fiber (pounds).
T_a = sum of forces on tension side = area OLT (pounds).
C_a = sum of forces on compression side = area OUC*l* (pounds).
d_t = distance of center of gravity of tension area from neutral plane (inches).
d_c = distance of center of gravity of compression area from neutral plane (inches).
M_r = sum of the internal moments about the point O (inch-pounds).

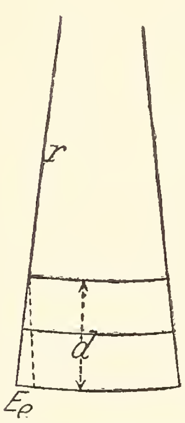


FIG. 101.—Fiber distortion in unit length of beam, at elastic limit.

The formulas connecting these quantities are derived as follows:

To find E_e let fig. 101 represent a portion of the beam one unit in length bent to its elastic limit; then,

$$\frac{E_e}{1}=\frac{d}{r},$$

where r is the radius of curvature, but from fundamental formulas true at elastic limit

$$-\frac{1}{r}=\frac{m}{EI}=\frac{Pl}{4ET}=\frac{12\Delta_e}{l^2}\ \therefore (1)\ E_e=\frac{12\Delta_e d}{l^2}.$$

Since this involves only geometric relations, it is true also at rupture (since the beam preserves its original form).

$$(2)\ E_r=\frac{12\Delta_r d}{l^2}.$$

To find d_p and T:

Since the sum of stresses on the tension side = sum of stresses on compression side,

$$\text{the area OLT} = \text{area OUC}l \therefore \frac{d_p}{2}T=(E_r-d_p)C-\frac{E_eC}{4} \text{ and } T=\frac{d_pC}{\frac{1}{2}E_e}$$

from the similar triangle OLT and Oel (fig. 100),

$$\therefore \frac{d_p{}^2 C}{E_e} = (E_r - d_p)\, C - \frac{E_e}{4} C,$$

whence,

(3) $d_p = \sqrt{E_r \times E_e} - \frac{E_e}{2}$,

and after d_p is found, T can be obtained:

(4) $T = \frac{d_p C}{\frac{1}{2} E_e}$.

Now, when the vertical line LU is assumed to represent the real depth of the beam in inches $= d$, every vertical measure will be changed in the ratio $\frac{d}{E_r}$ (see fig. 102); whence,

(5) $d_r = \frac{d}{E_r} d_p$

(real distance of neutral plane from tension side).

(6) $d_e = \frac{1}{2} \frac{d}{E_r} E_e$

($\frac{1}{2}$ because E_e total distortion, while d_e is the distance on one side of the neutral plane).

The area OLT would then become:

(7) $T_a = \frac{d_r T}{2}$, and the area OUCl =

(8) $C_a = (d - d_r)\, C - (\frac{d_e}{2} \times C)$

(C_a must equal T_a).

The distance of centers of gravity would be:

(9) $d_t = \frac{2}{3} d_r$,

(10) $d_c = \frac{d - d_r}{2} + \frac{d_e}{4}$,

and the sum of internal moments.

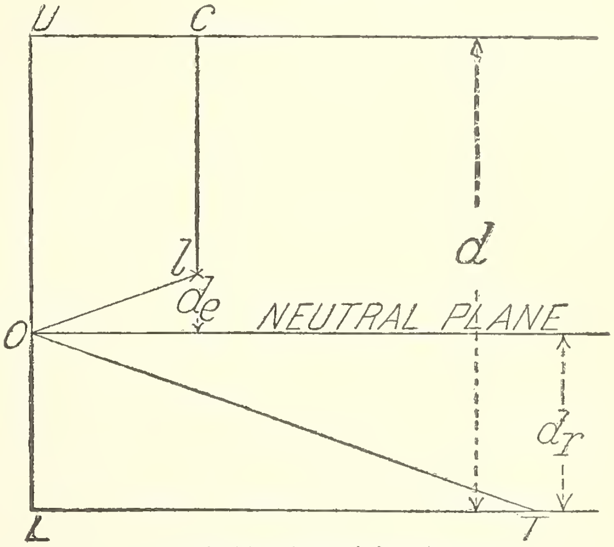


FIG. 102.—Position of neutral plane at rupture.

(11) $M_r = (C_a d_c + T_a d_t) b$, and since $C_a = T_a$, hence $M_r = C_a (d_c + d_t) b$.

But since the sum of internal moments equals the sum of external moments:

$$\frac{P_r l}{4} = M_r = C_a (d_c + d_t) b.$$

And since P_r is the breaking load of the beam, and C_a involves only the compression endwise strength and lineal dimensions, we have a formula directly connecting the breaking load of a beam with the compression strength.[1]

Application of these formulæ.—Unfortunately no tests have been made to study the application of these formulæ directly and in particular. The tests on beams published in this circular were made for a different purpose. For the purpose of ascertaining the correctness of the formulæ only the tests made on large beams have been utilized, since in these the deflections were specially accurately measured. In addition to the quantities to be calculated already given in this discussion, the fiber stress at the true elastic limit is also calculated, and called S_e, to be compared with C, and the load producing it, P_e, is also set down as an observed quantity. If the modulus of rupture, R, has already been calculated by the "ordinary formula," S_e can be obtained from the relation $\frac{S_e}{R} = \frac{P_e}{P_r}$ and

(12) $S_e = \frac{P_e}{P_r} R$.

The modulus of elasticity at true elastic limit E_e is recomputed as a check, and of course is:

$$(13)\ E_e = \frac{S_e}{\frac{1}{2} E_e}.$$

Since P_e is an arbitrary quantity within certain limits, and can not be determined with any degree of accuracy, S_e will be found to differ more or less from C. For these reasons, however, C is a more reliable value for the true elastic limit than S_e itself, and in the formulæ is used as such; for instance, E_e is the fiber distortion produced by the same load which produces a fiber stress = C, not by the load which produces S_e.

The following table exhibits the results of applying the formulæ to the data from these tests:

[[1] The factors $d_c + d_t$, within such limits as the cross-bending strength is constant, are constants; they will have to be ascertained by actual experiment for each species and quality, and might then be expressed as a proportion of the depth. In the material used, pine as well as oak, it appears to be about 3/5. The material on which this relationship has been mainly studied was green wood, and it may be questioned whether the factors d_c and d_t would remain the same in material of all moisture conditions. There is no logic which would lead us to expect a difference greater than the limits of "maximum uniformity," i. e., 10 per cent. A few comparisons of data obtained from material of other species with varying moisture percentage indicate that a difference does not exist.—B. E. F.]

Relation of results observed and calculated by usual methods and results calculated by Neely's formulæ.

Kind of wood.	Original number of beam.	Data observed and calculated by usual methods.										
		Compression endwise strength.	Bending strength.	Load at rupture.	Modulus of elasticity.	Deflection at rupture.	Dimensions of beams.			Load at true elastic limit.	Deflection at true elastic limit.	Actual sum of external moments about point O at rupture.
							Length.	Depth.	Breadth.			
		C	R	P_r	E	Δ_r	l	d	b	P_e	Δ_e	$\frac{P_r l}{4}$
		Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	1,000 lbs.	Inches.				Lbs.	Inch.	Inch pds. 1,000.
Shortleaf pine	12	*3,850*	7,360	28,000	**1,711**	3.10	192.0	11.87	7.87	13,000	1.02	**1,344**
Do	28	*3,590*	6,670	23,500	**1,483**	6.24	216.0	11.9	8.2	13,300	1.80	**1,269**
Do	9	*4,030*	8,300	32,800	**1,630**	6.16	192.0	12.0	8.0	19,000	1.50	**1,574**
Do	10	*3,900*	7,440	29,400	**1,340**	4.31	192.0	12.0	8.0	17,000	1.39	**1,411**
Do	13	*4,100*	7,320	29,800	**1,540**	4.06	192.0	12.1	8.1	17,000	1.36	**1,430**
Do	29	*4,450*	7,410	24,500	**1,703**	4.86	216.0	11.75	7.9	16,000	1.92	**1,323**
Do	33	*4,350*	7,450	26,400	**2,017**	3.36	216.0	12.06	8.0	16,000	1.48	**1,425**
Do	38	*4,500*	7,710	27,240	**1,718**	5.57	216.0	12.0	7.95	16,000	1.77	**1,470**
Longleaf pine	43	*5,300*	8,850	33,550	**1,715**	4.90	216.0	12.3	8.1	20,000	1.97	**1,811**
White pine	51	*3,330*	5,300	18,700	**1,320**	3.75	216.0	12.1	7.95	12,000	1.69	**1,009**
Red oak	3	*3,030*	6,570	25,800	**1,646**	7.94	192.0	12.0	8.0	9,000	1.50	**1,238**
Do	4	*4,460*	8,640	31,500	**1,825**	5.93	216.0	12.25	8.0	20,000	1.90	**1,701**
Do	8	*3,470*	6,870	26,000	**1,485**	6.70	216.0	12.25	8.37	14,000	1.71	**1,404**

Kind of wood.	Results calculated by Neely's formulæ.												
	Sum of internal moments about point O at rupture.	Bending strength at true elastic limit.	Total fiber distortion due to bending.		Modulus of elasticity at true elastic limit.	Distortion in extreme tension fiber at rupture.	Real distance of neutral plane at rupture.		Stress at rupture of extreme tension fiber.	Sum of forces for unit width of beam.		Distance from neutral plane of center of gravity.	
			At elastic limit.	At rupture.			From tension side of beam.	From that fiber on compression side which has just reached elastic limit.		On tension side.	On compression side.	Of tension area.	Of compression area.
	M_r	S_e	E_e	E_t	E_c	d_p	d_r	d_c	T	T_s	C_s	d_t	d_c
	Inch pds. 1,000.	Lbs.	Inches.		1,000 lbs.	Inches.			Lbs. per sq. in.	Lbs.		Inches.	
Shortleaf pine	**1.334**	*3,420*	0.0039	0.0120	**1,752**	0.0049	4.85	3.86	9,700	23,400	23,300	3.23	3.99
Do	**1.350**	*3,780*	0.0055	0.019	**1,373**	0.0075	4.70	3.44	9,810	23,053	22,760	3.13	4.03
Do	**1,541**	*4,800*	0.0059	0.0240	**1,630**	0.0089	4.45	1.47	12,200	27,100	27,400	2.97	4.14
Do	**1,392**	*4,300*	0.0054	0.0168	**1,400**	0.0068	4.86	1.93	9,800	24,000	24,000	3.24	4.05
Do	**1,460**	*4,180*	0.0053	0.0158	**1,570**	0.065	5.00	2.01	9,920	24,800	25,010	3.33	4.03
Do	**1,410**	*4,800*	0.0058	0.0150	**1.703**	0.0064	5.01	2.27	9,820	24,600	24,900	3.34	3.94
Do	**1,394**	*4,520*	0.0046	0.0104	**2,000**	0.0047	5.45	2.84	8,350	22,700	22,600	3.63	4.03
Do	**1,571**	*4,590*	0.0055	0.0172	**1,670**	0.0069	4.90	1.92	11,300	27,600	27,600	3.26	4.03
Longleaf pine	**1,887**	*5,330*	0.0062	0.0155	**1,718**	0.0067	5.32	2.46	11,500	30,500	30,500	3.54	4.10
White pine	**1,085**	*3,400*	0.050	0.0116	**1,340**	0.0051	5.30	2.60	6,780	18,000	18,000	3.53	4.05
Red oak	**1,255**	*2,300*	0.0059	0.0310	**1,642**	0.0106	4.10	1.14	11,000	22,500	22,200	2.73	4.23
Do	**1,675**	*5,480*	0.0060	0.0187	**1,828**	0.0076	4.98	1.96	11,330	28.100	28.100	3.32	4.13
Do	**1,437**	*3,700*	0.0050	0.0200	**1,480**	0.0075	4.60	1.53	10,400	23,900	23,600	3.07	4.21

NOTE.—Columns of figures in same distinctive type to be compared one with the other.

In order to see how far the formulæ may be applicable to beams of the same material the data obtained on the small beams cut from one of the large beams were subjected to scrutiny, basing the calculations on the data from the adjoining compression block. The calculated result compared with the actual breaking load showed a most convincing similarity, as will be apparent from the table herewith presented:

Strength of small beams, calculated by Neely's formulæ from compression strength, on the assumption that the relative position of the neutral plane at rupture is the same as found in large beams.

[Shortleaf pine, large beam No. 13, special series.]

	Data observed in testing.						Results calculated by Neely's formulæ.											
	Dimensions of beams.								Real distance of neutral plane at rupture.			Sums of forces for unit width of beam.		Distance from neutral plane of center of gravity.				
Number of beam.	Length.	Depth.	Breadth.	Bending strength as calculated by ordinary formula.	Compression endwise.	Observed load at rupture.	Load at rupture, as calculated by Neely's formula from compression strength.	Bending strength at true elastic limit.	From tension side of beam.	From that fiber on compression side which has just reached elastic limit.	Stress at rupture of extreme tension fiber.	On tension side.	On compression side.	Of tension area.	Of compression area.	Sum of internal moment about point O at rupture.	Load at true elastic limit.	Deflection at true elastic limit.
	l	d	b	R	C	P	P_r	S_e	d_r	d_e	T	T_a	C_a	d_t	d_c	M_r	P_e	Δ_e
	Inches.			Lbs. per sq. in.		Lbs.		Lbs. per sq. in.	Inches.		Lbs. per sq. in.	Lbs.	Lbs.	Inches.		Inch pounds.	Lbs.	Inch.
2	50	3.51	3.56	7,350	**4,430**	**4,300**	**4,708**	**3,760**	1.46	1.23	10,517	7,677	7,719	0.97	1.18	58,760	2,200	0.296
3	50	3.75	3.37	7,910	**4,610**	**5,000**	**5,310**	**4,430**	1.56	1.31	10,979	8,564	8,552	1.04	1.26	66,380	2,800	0.391
4	50	3.55	3.60	7,790	**4,560**	**4,710**	**5,057**	**3.969**	1.48	1.24	10,885	8,055	8,026	0 99	1.19	63,216	2,400	0.413
5	50	3.49	3.50	8,230	**4,070**	**4,680**	**4,203**	**4,220**	1.45	1.22	9,675	7,014	7,061	0.97	1.17	52,535	2,400	0.345
6	50	3.58	3.54	7,750	**4.150**	**4,690**	**4.571**	**4,296**	1.49	1.25	9,894	7,371	7,376	0.99	1.20	57,144	2,600	0.356
7	50	3.53	3.50	7,810	**4,160**	**4,540**	**4,420**	**4,129**	1.47	1.23	9,943	7,308	7,290	0.98	1.18	55,248	2,400	0.431
8	50	3.56	3.54	7,470	**3,870**	**4,470**	**4.578**	**4,178**	1.48	1.25	9,164	7,381	6,840	0.99	1.20	57,222	2,500	0.440
a 9	50	3.52	3.54	5,130	**3,880**	**3,000**	**4,169**	**3,078**	1.47	1.23	9,274	6,816	6,751	0.98	1.18	52,118	1,800	0.328
10	50	3.52	3.45	7,510	**3,680**	**4,280**	**3,854**	**3,860**	1.47	1.23	8,796	6,465	6,403	0.98	1.18	48,177	2,200	0.387
11	50	3.47	3.52	6,370	**3,750**	**3,600**	**3,312**	**3,893**	1.44	1.21	8,926	6,427	6,485	0.96	0.87	41,400	2,200	0.372
12	50	3.48	3.54	6,580	**3,540**	**3,760**	**3,697**	**3,395**	1.45	1.22	8,415	6,101	6,124	0.97	1.17	46,219	1,940	0.300

a Failed, due to knot.

NOTE.—Columns of figures in same distinctive type to be compared one with the other.

On the whole, it is in no way boastful to assert that this work has already furnished practical data enough to more than pay the expenses incurred ten times over; that its fruits are not half gathered, and that for more than a quarter of a century its results will serve as a basis for the user of wood and as the guide to the teacher and experimenter.

Development of the Science of Timber Physics and Methods Employed in the Investigation.

Since the elaborate plan and methods of this study of our woods denotes an entirely new departure in timber investigations, at least in our country, it is only fitting to place the credit for its conception, for the elaboration of the plan, the organization of the work, and the persistent prosecution of the same in spite of many drawbacks and lack of support. This credit belongs to Dr. B. E. Fernow, chief of the Division of Forestry. The plan was first foreshadowed in his second report (1887, p. 37) as chief of that division, and the word "timber physics" was there used for the first time, and the essentials of the future plan were there discussed. In a small tentative manner the first steps to put it in operation were made in 1888. In the report for 1889 we read:

The investigations into the technology of our timbers and especially into the conditions upon which the qualities of our timbers depend—for which Mr. Roth of Ann Arbor has begun preliminary studies—has also made but slow progress for lack of means.

In the report for 1890 we find, besides an account of the tests on Northern and Southern oaks referred to before, the statement that "by the increase of appropriations the forest technological investigations referred to in former reports have become possible on a scale which was hitherto unattainable," and a description of the plans is given. But the first fuller statement of the

development of the investigation and its methods was not published until 1892, in Bulletin 6, in which Mr. Fernow described the aims, objects, and methods at length.

In the report for 1890 the following language is used:

TIMBER TESTS.

While the use of wood pulp and other substitutes may displace in many ways the use of wood in its natural state, there will always be desirable qualities inherent in the latter that make its use indispensable. Hence the desirability of knowing the qualities of our timbers and, if possible, of knowing the conditions under which the wood crop will develop the desirable qualities.

Much work and useful work is done in the world by the rule of thumb. All such work is not reliable and certainly not economical. With the need of greater economy in production, the need of more accurate measuring arises, and with that the need of more specific knowledge of the materials to be measured.

Wood is one of the materials which has been measured by the rule of thumb longer than others. Iron and other metals used in the arts have their properties much more accurately determined than wood material. Especially in the United States, when we speak of quality of our timbers, it can only be in general terms; we lack definite data.

One difficulty in determining reliably the qualities of our timbers lies in the fact that living things are rarely precisely alike. Every tree differs from every other tree, and the material taken from the one has a different value from that taken from the other of the same species. Yet every tree has some characteristics in common with all those grown under similar conditions. But even these common properties differ in degree in different individuals. Individual variation tends to obscure relationship.

The factors which determine the quality of timbers are found directly in the structure of the wood, and it is possible from a mere ocular examination to judge to some extent what qualities may be expected from a given piece of timber, although even in this direction our knowledge is very incomplete, and but few definite relations between structure and quality, or between physical and mechanical properties, are established. We know that the width of the annual rings, their even growth, the closeness of grain, the length, number, thickness, and distribution of the various cell elements, the weight, and many other physical appearances and properties of the wood influence its quality, yet the exact relation of these is but little studied. Conjectures more or less plausible, suppositions, and a few practical experiences preponderate over positive knowledge and results of experiments. Again we know, in a general way, that structure and composition of the wood must depend upon the conditions of soil, climate, and surroundings under which the tree is grown, but there are only few definite relations established. We are largely ignorant as to the nature of our wood crop, and still more so as to the conditions necessary to produce desirable qualities, and since forestry is not so much concerned in producing trees as in producing quality in trees, to acquire or at least enlarge this knowledge must be one of the first and most desirable undertakings in which this Division can engage.

Accordingly a comprehensive plan has been put into operation to study systematically our more important timber trees.

It will at once be understood that as long as the qualities are to be referred to the conditions under which the tree is grown, the collection of the study material must be made with the greatest care, and the material must be accompanied with an exhaustive description of these conditions. Since, further, so much individual variation seems to exist in trees grown under seemingly the same conditions, a large number must be studied in order to arrive at reliable average values. For the present it has been decided to study the pines, especially the white pine and the three Southern lumber pines.

In selecting localities for collecting specimens, a distinction is made between station and site.

By station is understood a section of country (or any places within that section) which is characterized in a general way by similar climatic conditions and geological formation. Station, then, refers mainly to the general geographical situation. Site refers to the local conditions and surroundings within the station, such as difference of elevation, of exposure, of physical properties and depth of the soil, nature of subsoil, and forest conditions, such as mixed or pure growth, open or close stand, etc.

The selection of characteristic sites in each station requires considerable judgment.

On each site five full-grown trees are to be taken, four of which are to be representative average trees; the fifth or "check" tree, however, should be the best developed tree that can be found on the site. Some additional test trees will be taken from the open and also a few younger trees. The trees are cut into varying lengths, and from each log a disk of 6-inch height is secured, after having marked the north and south sides and noted the position of the log in the tree.

The disks are sent for examination of the physical and physiological features to the Michigan University, while the logs, and later on special parts of the disks are to be sent to the test laboratory of the Washington University of St. Louis. Here, for the first time, a systematic series of beam tests will be made and compared with the tests on the usual small laboratory test pieces. Such tests with full-length beams in comparison with tests on small specimens promise important practical results, for a few tests have lately developed that large timbers seem to have but little more than one-half the strength they were credited with by standard authorities, who relied upon the tests on small specimens.

From the "check" tree mentioned before only clear timber is to be chosen, in order to ascertain the possibilities of the species and also to establish, if possible, a relation between such clear timber and that used in general practice, where elements of weakness are introduced by knots and other blemishes.

An authority on engineering matters writes regarding this work:

"Inasmuch as what passes current among engineers and architects as information on the strength of timber is really misinformation, and that no rational designing in timber can be done until something more reliable is furnished in this direction, the necessity for making a competent and trustworthy series of such tests is apparent. This is a work which the Government should undertake if it is to be impartial and general."

A careful record of all that pertains to the history and conditions of the growth from which the test pieces come, and of their minute physical examination, will distinguish these tests from any hitherto undertaken on American timbers.

The disk pieces will be studied to ascertain the form and dimensions of the trunk, the rate and mode of its growth, the density of the wood, the amount of water in the fresh wood, the shrinkage consequent upon drying, the structure of the wood in greatest detail, the strength, resistance, and working qualities of the wood, and lastly, its chemical constituents, fuel value, and composition of the ash.

In Bulletin 6 we are introduced to the science of "timber physics" in the following language:

Whenever human knowledge in any particular direction has grown to such an extent and complexity as to make it desirable for greater convenience and better comprehension to group it, correlate its parts, and organize it into a systematic whole, we may dignify such knowledge by a collective name as a new science or branch of science. The need of such organization is especially felt when a more systematic progress in accumulating new knowledge is contemplated. In devising, therefore, the plans for a systematic and comprehensive examination of our woods it has appeared desirable to establish a system under which is to be organized all the knowledge we have or may acquire of the nature and behavior of wood.

To this new branch of natural science I propose to give the name of "timber physics," a term which I have used first in my report for 1887, when, in devising a systematic plan of forestry science the absence of a collective name for this class of knowledge became apparent.

While forest biology contemplates the forest and its components in their living condition, we comprise in timber physics all phenomena exhibited in the dead material of forest production.

The practical application of timber or wood for human use, its technology, is based upon the knowledge of timber physics, and under this term we comprise not only the anatomy, the chemical composition, the physical and mechanical properties of wood, but also its diseases and defects, and a knowledge of the influences and conditions which determine structure, physical, chemical, mechanical, or technical properties and defects. This comprehensive science, conceived under the name here chosen, although developed more or less in some of its parts, has never yet been dignified by a special name, nor has a systematic arrangement of its parts been attempted before. It comprises various groups of knowledge derived from other sections of science, which are neither in themselves nor in their relations to each other fully developed.

While plant physiology, biology, chemistry, anatomy, and especially xylotomy, or the science of wood structure, are more or less developed and contribute toward building up this new branch of science, but little knowledge exists in regard to the interrelation between the properties of wood on one side and the modifications in its composition and structure on the other. Even the relation of the properties of various woods, as compared with each other, and their distinct specific peculiarities are but little explored and established. Less knowledge still exists as to the relation of the conditions which surround the living tree to the properties which are exhibited in its wood as a result of its life functions. Suppositions and conjectures more or less plausible preponderate over positive knowledge derived from exact observation and from the results of experiments. Still less complete is our knowledge in regard to the relation of properties and the methods and means used for shaping or working the wood.

The close interrelation of all branches of natural science is now so well recognized that I need not remind my readers that hard and fast lines can not be drawn whereby each field of inquiry is confined and limited; there must necessarily be an overlapping from one to the other. Any system, therefore, of dividing a larger field of inquiry into parts is only a matter of convenience; its divisions and correlations must be to some extent arbitrary and varied according to the point of view from which we proceed to divide and correlate.

There are two definite and separate directions in which this branch of natural science needs to be developed, and the knowledge comprised in it may be divided accordingly. On one side it draws its substance largely from the more comprehensive fields of botany, molecular physics, and chemistry, and on the other side it rests upon investigations of the wood material from the point of view of mechanics or dynamics. In the first direction we are led to deal with the wood material as it is, its nature or appearance and conditions; in the second direction we consider the wood material in relation to external mechanical forces, its behavior under stress.

The first part is largely descriptive, concerned in examining gross and minute structures, physical and chemical conditions and properties, and ultimately attempting to explain these by referring to causes and conditions which produce them. This is a field for investigation and research by the plant physiologist in the laboratory in connection with studies of environment in the forest. The second part, which relies for its development mainly upon experiment by the engineer, deals with the properties which are a natural consequence of the structure, physical condition, and chemical composition of the wood as exhibited under the application of external mechanical forces. It comprises, therefore, those studies which contemplate the wood substance, with special reference to the uses of man, and forms ultimately the basis for the mechanical technology of wood or the methods of its use in the arts.

The correlation of the results of these two directions of study as cause and effect is the highest aim and ultimate goal, the philosophy of the science of timber physics. Timber physics, in short, is to furnish all necessary knowledge of the rational application of wood in the arts, and at the same time, by retrospection, such knowledge will enable us to produce in our own forest growth qualities of given character.

Conceived in this manner it becomes the pivotal science of the art of forestry, around which the practice both of the consumer and producer of forest growth moves.

The first part of our science would require a study into gross and minute anatomy, the structure of the wood, form, dimensions, distribution, and arrangement of its cell elements and of groups of structural parts, not only in order to distinguish the different woods, but also to furnish the basis for an explanation of their physical and mechanical properties. We next would class here all investigations into the physical nature or properties of the wood material, which necessarily also involves an investigation into the change of these properties under varying conditions and influences. A third chapter would occupy itself with the chemical composition and properties of woods and their changes in the natural process of life, which predicate the fuel value and durability as well as the use of the wood in chemical technology.

Although, philosophically speaking, it would hardly seem admissible to distinguish between physical and mechanical properties or to speak of "mechanical" forces, for the sake of convenience and practical purposes it is desirable to make the distinction and to classify all phenomena and changes of nonliving bodies, or bodies without reference to life functions, into chemical, physical, and mechanical phenomena and changes. As chemical phenomena or changes, and therefore also conditions or properties, we class, then, those which have reference to atomic structure; as physical phenomena, changes, and properties those which refer to and depend on molecular arrangement, and as mechanical (molar) changes and properties those which concern the masses of bodies, as exhibited under the influence of external forces, without altering their physical or chemical constitution.

There is no doubt that this division is somewhat forced, since not only most or all mechanical (as here conceived) changes are accompanied or preceded by certain alterations of the interior molecular arrangement of the mass, but also many physical phenomena or properties, like density, weight, shrinkage, having reference to the mass, might be classed as mechanical; yet if we conceive that physical phenomena are always concerned with the "quantity of matter in molecular arrangement" and with the changes produced by interior forces, while the latter are concerned rather with the "position of matter in molecular arrangement" and with changes under application of exterior forces, the distinction assumes a practical value.

Our conception of these distinctions will be aided if we refer to the physical laboratory as furnishing the evidence of physical phenomena and to the mechanical laboratory as furnishing evidence of mechanical phenomena.

These latter, then, form the subject of our second or dynamic part of timber physics, which concerns itself to ascertain mainly by experiment, called tests, under application of the laws of elasticity, the strength of the material and other properties which are exhibited as reactions to the influence of applied stresses, and those which need consideration in the mechanical use of the material in the various arts.

Having investigated the material in its normal condition, we would necessarily come to a consideration of such physical and chemical conditions of the material as are abnormal and known as disease, decay, or defects.

Finally, having determined the properties and their changes as exhibited in material produced under changing conditions or differing in physical and structural respects, it would remain the crowning success and goal of this science to relate mechanical and physical properties with anatomical and physiological development of the wood substance.

The subject-matter comprised in this branch of applied natural science, then, may be brought into the following schematic view:

TIMBER PHYSICS, OR THE SCIENCE OF WOOD.

I.—WOOD STRUCTURE OR XYLOTOMY.

(*a*) *Exterior form.*

Here would be described the form development of timber in the standing tree, differentiated into root system, root collar, bole or trunk crown, branches, twigs; relative amounts of material furnished by each.

(*b*) *Interior structural appearance;* differentiation and arrangement of groups of structural elements.

Here would be described the gross structural features of the wood, the distribution and size of medullary rays, vessels, fibro-vascular bundles, as exhibited to the naked eye or under the magnifying glass on tangential, radial, and transverse sections; the appearance of the annual rings, their size, regularity, differentiation into summer and spring wood, and all distinguishing features due to the arrangement and proportion of the tissues composing the wood.

(*c*) *Minute anatomy or histology;* differentiation and arrangement of structural elements.

Here the revelations of the microscope are recorded, especially the form, dimensions, and structure of the different kinds of cells, their arrangement, proportion, and relative importance in the resulting tissues.

(*d*) *Comparative classification of woods,* according to *structural* features.

(*e*) *Laws of wood growth* with reference to structural results.

Discussion of the factors that influence the formation of wood in the standing tree.

(*f*) *Abnormal formations.*

Burls, bird's eye, curly, wavy, and other structural abnormities and their causes.

II.—PHYSICAL PROPERTIES, i. e., properties based on molecular (physical) constitution.

(*a*) *Exterior appearance.*

Such properties as can be observed through the unaided senses, as color, gloss, grain, texture, smell, resonance.

(*b*) *Material condition.*

Such properties or changes as are determined by measurements, as density or weight, water contents and their distribution, volume, and its changes by shrinkage and swelling.

(c) *Classification of woods* according to *physico-technical* properties, i. e., such physical properties as determine their application in the arts.

III.—Chemical properties, i. e., properties based on atomic (chemical) constitution.

(a) *General chemical analysis of wood* (qualitative and quantitative).

Here would be discussed the chemical constitution of different woods and different parts of trees and their changes due to physiological processes, age, conditions of growth, etc.

(b) *Carbohydrates of the wood.*

Here would be more specially discussed cellulose and lignin, cork formations, organic contents and their changes, and such properties as predicate the fuel value of woods, their manufacture into charcoal, their food value, pulping qualities, etc.

(c) *Extractive materials.*

A knowledge of these underlies the application of wood in the manufacture of tan extracts, resin, and turpentine, tar, gas, alcohol, acids, vanillin, etc.

(d) *Antiseptic materials.*

A knowledge of those chemical properties which predicate durability and underlie processes of increasing the same.

(e) *Mineral constituents.*

A knowledge of these in particular will establish the relation of wood growth to mineral constituents of the soil and also serve as basis for certain technical uses (potash).

IV.—Mechanical properties, i. e., properties based on elastic conditions exhibited by the aggregate mass under influence of exterior (mechanical) forces.

(a) *Form changes without destruction of cohesion*, commonly called elasticity, flexibility, toughness.

(b) *Form changes with destruction of cohesion*, commonly called strength (tensile, compressive, torsional, shearing), cleavability, hardness.

V.—Technical properties, i. e., properties in combination.

Here would be considered the woods with reference to their technical use, their application in the arts, which is invariably based upon a combination of several physical or mechanical properties.

VI.—Diseases and faults.

Here would be treated the changes in structure and properties from the normal to abnormal conditions, due to influences acting upon the tree during its life or upon the timber during its use.

VII.—Relation of properties to each other.

Here would be discussed the connection which may be established between structure, physical, chemical, and mechanical properties, and also between these and the conditions of growth under which the material was produced. The philosophy of the entire preceding knowledge would here be brought together.

To contribute toward this important branch of human knowledge and to help in the building of its foundation, the work undertaken by the Division of Forestry described in this bulletin was designed by the writer; and, in order to build with a knowledge of what has been done before on this structure, a brief review of the progress in the development of timber physics seemed advisable.

This historical review is then given. From this we deem it appropriate to quote the portion which refers to efforts in the United States up to the time of the writing to establish data regarding the mechanical properties of our timber:

AMERICAN WORK.

While it may be possible to work out the general laws of relation between physical and mechanical properties on material of European origin, for practical purposes we can not rely upon any other data than those ascertained from American timbers, and so far as dependence of quality on conditions of growth are concerned this truth is just as patent. Although in the United States probably more timber has been and is being used than in any other country, but little work has been done in the domain of timber physics.

Among the earliest American experiments falling in the domain of timber physics may be cited those of Marcus Bull to determine "the comparative quantities of heat evolved in the combustion of the principal varieties of wood and coal used in the United States for fuel," made in the years 1823 to 1825 and published in 1826. Here the experiments of Lavoisier, Crawford and Dalton, and Count Rumford on similar lines are discussed and followed by an able series of experiments and discussion on American woods and coals.

The only comprehensive work in timber physics ever undertaken on American timbers is that of Mr. T. P. Sharples, in connection with the Tenth Census, and published in 1884, Vol. IX, on the Forests of North America. Comprehensiveness, however, has been sought rather in trying to bring under examination all the arborescent species than in furnishing fuller data of practical applicability on those from which the bulk of our useful material is derived. "The results obtained," the author says, "are highly suggestive; they must not, however, be considered conclusive, but rather valuable as indicating what lines of research should be followed in a more thorough study of this subject."

Not less than 412 species were examined in over 1,200 specimens. The results are given in five tables, besides four comparative tables of range, relative values, averages, etc. The specimens were taken "in most cases from the butt cut and free from sap and knots;" the locality and soil from which the tree came are given in most cases, and in some its diameter and layers of heart and sapwood; determinations were made of specific gravity, mineral ash per cent, and from these data fuel values were calculated.

The specimens tested were "carefully seasoned." For transverse strain they were made 4 centimeters (1.57 inches) square, and a few of double these dimensions, with 1 meter (3.28 feet) span.

One table illustrates "the relation between the specific gravity and the transverse strength of the wood of species, upon which a sufficient number of tests has been made to render such a comparison valuable." This table seems to show that in perfect specimens weight and strength stand in close relation. A few tanning determinations on the bark of a few species are also given.

The object of the work as stated, namely, to be suggestive of a more thorough study of the subject, has certainly been fully and creditably attained. Of compilatory works, for use in practice and for reference, the following, published in the United States, may be cited:

De Volson Wood: Resistance of Materials (1871), containing rather scanty references to the work of Chevandier and Wertheim.

R. G. Hatfield: Theory of Transverse Strain (1877), which, besides other references, contains also twenty-three tables of the author's own test on white pine, Georgia pine, hemlock, spruce, white ash, and black locust, on sticks 1 by 1 inch by 1.6 feet in length.

William H. Burr: The Elasticity and Resistance of Materials of Engineering, third edition, 1890, a comprehensive work, in which many references are made to the work of various American experimenters.

Gaetano Lanza, in Applied Mechanics, 1885, lays especial stress on the fact that tests on small select pieces give too high values, and quotes the following experiments on long pieces. He refers to the work of Capt. T. J. Rodman, United States Army, published in Ordnance Manual, who used test pieces 2¾ by 5¼ inches and 5 feet length, without giving any reference to density or other facts concerning the wood; and to Col. Laidley's United States Navy test (Senate Ex. Doc. 12, Forty-seventh Congress, first session, 1881), who conducted a series of experiments on Pacific slope timbers, "white and yellow pine," 12 feet long and 4 to 5 by 11 to 12 inches square, giving also account of density and average width of rings.

Lastly, the author's own experiments, made at the Watertown Arsenal for the Boston Manufacturers' Mutual Fire Insurance Company, on the columnar strength of "yellow pine" and white oak, 12 feet long and 6 to 10 inches thick, are brought in support of the claim that such tests show less than half the unit strength of those on small pieces. Data as to density, moisture, or life history of the specimens are everywhere lacking.

R. H. Thurston, Materials of Engineering, 1882, contains, perhaps, more than any other American work on the subject, devoting, in Chapters II and III, 117 pages to timber and its strength, and in the chapter on Fuel several pages to wood and charcoal, and the products of distillation. It also gives a description of some twenty-five kinds of American and of a few foreign timber trees, with a description of the structure and their wood in general; directions for felling and seasoning; discusses briefly shrinkage, characteristics of good timber, the influence of soil and climate on trees and their wood, and of the various forms of decay of timber, methods of preservation and adaptation of various woods for various uses, much in the same manner as Rankine's Manual of Civil Engineering, from which many conclusions are adopted. The author refers, besides foreign authorities, to the following American investigators:

G. H. Corliss (unpublished?) is quoted as claiming that proper seasoning of hickory wood increases its strength by 15 per cent.

R. G. Hatfield is credited with some of the best experiments on shearing strength, published in the American House Carpenter.

Prof. G. Lanza's experiments are largely reproduced, also Trautwine's on shearing, and some of the author's own work on California spruce, Oregon pine, and others, especially in torsion, with a specially constructed machine, an interesting plate of strain diagrams accompanying the discussion.

In connection with the discussion by the author on the influence of prolonged stress, there is quoted as one of the older investigators, Herman Haupt, whose results on yellow pine were published in 1871 (Bridge Construction).

Experiments at the Stevens Institute of Technology are related, with the important conclusion that a load of 60 per cent of the ultimate strength will break a stick if left loaded (one small test piece having been left loaded fifteen months with this result).

In addition the following list of references to American work in timber physics is here inserted, with a regret that it has not been possible to include all the stray notes which may be in existence but were not accessible. Those able to add further notes are invited to aid in making this reference list complete:

Abbott, Arthur V. Testing machines, their history, construction, and use. With illustrations of machines, including that at Watertown Arsenal. Van Nostrand's Magazine, 1883, vol. 30, pp. 204, 325, 382, 477.

Day, Frank M., University of Pennsylvania. The microscopic examination of timber with regard to its strength. Read before American Philosophical Society, 1883.

Estrada, E. D. Experiments on the strength and other properties of Cuban woods. Investigations carried on in the laboratory of the Stevens Institute. Van Nostrand's Magazine, 1883, vol. 29, pp. 417, 441.

Flint, ——. Report of tests of Nicaraguan woods. Journal of Franklin Institute, October, 1887, pp. 289-315.

Goodale, Prof. George L., Harvard University. Physiological Botany, 1885, chapters 1, 2, 3, 5, 8, 11, and 12.

Ihlseng, Magnus C., Ph. D. On the modulus of elasticity in some American woods, determined by vibration. Van Nostrand's Magazine, 1878, 19.

—— On a mode of measuring the velocity of sounds in woods. Read before the National Academy of Science, 1877; published in American Journal of Science and Arts, 1879, vol. 17.

Johnson, Thomas H. On the strength of columns. Paper read at annual convention of American Society of Civil Engineers, 1885. Transactions of the Society, vol. 15.

Kidder, F. E. Experiments at Maine State College on transverse strength of southern and white pine. Van Nostrand's Magazine, 1879, vol. 22.
——— Experiments with yellow and white pine. Van Nostrand's Magazine, 1880, vol. 23.
——— Experiments on the strength and stiffness of small spruce beams. Van Nostrand's Magazine, 1880, vol. 21
——— Influence of time on bending strength and elasticity. Journal of Franklin Institute, 1882. Proceedings Institute of Civil Engineering, vol. 71.
Lanza, Gaetano, professor Massachusetts Institute of Technology. Address before American Society of Mechanical Engineers, describing the 50,000-pound testing machine at Watertown Arsenal and tests of strength of large spruce beams. Journal of Franklin Institute, 1883.
——— Report of Boston Manufacturers' Mutual Fire Insurance Company of tests made with Watertown machine on columns of pine, whitewood, and oak of dimensions used in cotton and woolen mills. See summary and tables of same in Burr's Elasticity and Resistance of the Materials of Engineering, p. 480.
Macdonald, Charles. Necessity of government aid in making tests of materials for structural purposes. Paper read before the American Institute of Mining Engineers. Van Nostrand's Magazine, 1882, vol. 27, p. 177.
Norton, Prof. W. A., Yale College. Results of experiments on the set of bars of wood, iron, and steel after a transverse set. Experiments discussed in two papers read before the National Academy of Science, 1874 and 1875. Published in Van Nostrand's Magazine, 1887, vol. 17, p. 531.
——— Description of machine used is given in proceedings of the A. A. A. S., eighteenth meeting, 1869.
Parker, Lieut. Col. F. H., United States Ordnance Department. Report of tests of American woods by the testing machine, United States Arsenal, Watertown, under supervision of Prof. C. S. Sargent, for the Census Report, 1880. Senate Ex. Doc. No. 5, Forty-eighth Congress, first session, 1882–83.
——— Report of experiments on the adhesion of nails, spikes, and screws in various woods, as made at Watertown Arsenal. Senate Ex. Doc. No. 35, Forty-ninth Congress, first session, 1883–84, and in report on tests of metals and other materials for industrial purposes at Watertown Arsenal, 1888–89.
——— Also in report on tests of iron, steel, and other materials for industrial purposes at Watertown Arsenal, 1886-87, pp. 188, 189.
——— Report on cubic compression of various woods, as shown by tests at Watertown Arsenal, 1885–86, in report on tests of metals, etc., for industrial purposes.
Philbrick, Professor, Iowa University. New practical formulas for the resistance of solid and built beams, girders, etc., with problems and designs. Van Nostrand's Magazine, 1886, vol. 35.
Pike, Prof. W. A. Tests of white pine, made in the testing laboratory of the University of Minnesota. Van Nostrand's Magazine, 1885, vol. 34, p. 172.
Rothrock, Prof. J. T., University of Pennsylvania. Some microscopic distinctions between good and bad timber of the same species. Read before American Philosophic Society.
Smith, C. Shaler, C. E. Summary of results of 1,200 tests of full-size yellow-pine columns. See W. H. Burr's Elasticity and Resistance of the Materials of Engineering, pp. 485–490.
Thurston, Prof. R. H., Cornell University. The torsional resistance of materials. Journal of Franklin Institute, 1873, vol. 65.
——— Experiments on torsion. Van Nostrand's Magazine, July, 1873.
——— Experiments on the strength, elasticity, ductility, etc., of materials, as shown by a new testing machine. Van Nostrand's Magazine, 1874, vol. 10.
———. The relation of ultimate resistance to tension and torsion. Proceedings of Institute of Civil Engineers, vol. 7, 1878.
———. The strength of American timber. Experiments at Stevens Institute. Paper before A. A. A. S., 1879. Journal of Franklin Institute, vol. 78, 1879.
———. Effect of prolonged stress upon the strength and elasticity of pine timber. Journal of Franklin Institute. vol. 80, 1880.
———. Influence of time on bending strength and elasticity. Proceedings A. A. A. S., 1881. Proceedings Institute of Civil Engineers, vol. 71.
Watertown Arsenal. Summary of results of tests of timber at, in Ex. Doc. No. 1, Forty-seventh Congress, second session. See Burr's Elasticity and Resistance of Materials of Engineering, pp. 486 and 535.
Wellington, A. M., C. E. Experiments on impregnated timber. Railroad Gazette, 1880.

Organization and Methods.

Although in the course of the investigations many minor and some more important changes in methods became necessary, the general plan was in the main adhered to. We consider it, therefore, desirable to restate from the same bulletin such portions as will explain the methods pursued. The work at the test laboratory at St. Louis, Mo., was described in full by Prof. J. B. Johnson, in charge, and the methods in the examination of the physical properties of the test material by the writer.

There are four departments necessary to carry on the work as at present organized, namely:

(1) The collecting department.

(2) The department of mechanical tests.

(3) The department of physical and microscopic examination of the test material.

(4) The department of compilation and final discussion of results.

The region of botanical distribution of any one species that is to be investigated is divided into as many stations as there seem to be widely different climatic or geological differences in its habitat. In each station are selected as many sites as there seem widely different soils, elevations, exposures, or other striking conditions occupied by the species. An expert collector describes carefully the conditions of station and site, under instructions and on blanks appended to this report. From each site five mature trees of any one species are chosen, four of which are average representatives of the general growth, the fifth, or "check" tree, the best developed that can be found. The trees are felled and cut into logs of merchantable size, and from the butt end of each log a disk 6 inches in height is sawed. Logs and disks are marked with numbers to indicate number of tree and number of log or disk, and their north and south sides are marked; their height in the tree from the ground is noted in the record. The disks are also weighed immediately, then wrapped in oiled paper and packing paper, and sent by mail or express to the laboratory, to serve the purpose of physical and structural examination. Some disks of the limbwood and of younger trees are also collected for other physical and physiological investigations, and to serve with the disks of the older trees in studying the rate of growth and other problems.

The logs are shipped to the test laboratory, there sawed and prepared for testing, carefully marked, and tested for strength.

The fact that tests on large pieces give different values from those obtained from small pieces being fully established, a number of large sticks of each species and site will be tested full length in order to establish a ratio between the values obtained from the different sizes. Part of the material is tested green, another part when seasoned by various methods. Finally, tests which are to determine other working qualities of the various timbers, such as adapt them to various uses, are contemplated

The disks cut from each log and correspondingly marked are examined at the botanical laboratory. An endless amount of weighings, measurings, countings, computings, microscopic examinations, and drawings is required here, and recording of the observed facts in such a manner that they can be handled. Chemical investigations have also been begun in the Division of Chemistry of the Department of Agriculture, the tannic contents of the woods, their distribution through the tree and their relation to the conditions of growth forming the first series of these investigations.

It is evident that in these investigations, carried on by competent observers, besides the main object of the work, much new and valuable knowledge unsought for must come to light if the investigations are carried on systematically and in the comprehensive plan laid out. Since every stick and every disk is marked in such a manner that its absolute position in the tree and almost the absolute position of the tree itself or at least its general condition and surroundings are known and recorded, this collection will be one of the most valuable working collections ever made, allowing later investigators to verify or extend the studies.

This significant prophetic language also occurs in this connection, which has finally been realized by the discovery of the relation between compression and beam strength:

> By and by it is expected that the number of tests necessary may be reduced considerably, when for each species the relation of the different exhibitions of strength can be sufficiently established, and perhaps a test for compression alone furnish sufficient data to compute the strength in other directions.

WORK AT THE TEST LABORATORY AT ST. LOUIS, MO.

SAWING, STORING, AND SEASONING.

On arrival of the logs in St. Louis they are sent to a sawmill and cut into sticks, as shown in fig. 103.

In all cases the arrangements shown in Nos. 1 and 2 are used, except when a detailed study of the timber in all parts of the cross section of the log is intended. A few of the most perfect logs of each species are cut up into small sticks, as shown in Nos. 3 and 4. The logs tested for determining the effects of extracting the turpentine from the Southern pitch pines were all cut into small sticks.

In all cases a "small stick" is nominally 4 inches square, but when dressed down for testing may be as small as 3½ inches square. The "large sticks" vary from 6 by 12 to 8 by 16 inches in cross section.

All logs vary from 12 to 18 feet in length. They all have a north and south diametral line, together with the number of the tree and of the log plainly marked on their larger or lower ends. The stenciled lines for sawing are

adjusted to this north and south line, as shown in the figures. Each space is then branded by deep dies with three numbers, as, for instance, thus: $\begin{matrix}25\\2\\4\end{matrix}$, which signifies that this stick was number 4, in log 2, of tree 25. A facsimile of the stenciling is recorded in the log book, and the sticks there numbered to correspond with the numbering on the logs. After sawing, each stick can be identified and its exact origin determined. These three numbers, then, become the identification marks for all specimens cut from this stick, and they accompany the results of tests in all the records.

The methods of sawing shown in Nos. 2 and 4 are called "boxing the heart;" that is, all the heart portion is thrown into one small stick, which in practice may be thrown away or put into a lower grade without serious loss. In important bridge, floor, or roof timbers, the heart should always be either excluded or "boxed" in this way, since its presence leads to checking and impairs the strength of the stick.

After sawing, the timbers are stored in the laboratory until they are tested. The "green tests" are made usually within two months after sawing, while the "dry tests" are made at various subsequent times. One end (60 inches) of each small stick is tested green, and the other end reserved and tested after seasoning. The seasoning is hastened in some cases by means of a drying box. The temperature of the inflowing air in this drying box is kept at about 100° F., with suitable precaution against checking of the wood, and the air is exhausted by means of a fan. The air is, therefore, somewhat rarefied in th box. The temperature is at all times under control. It operates when the fan is running, and this is only during working hours.

The mechanical and moisture test are then made according to known methods.

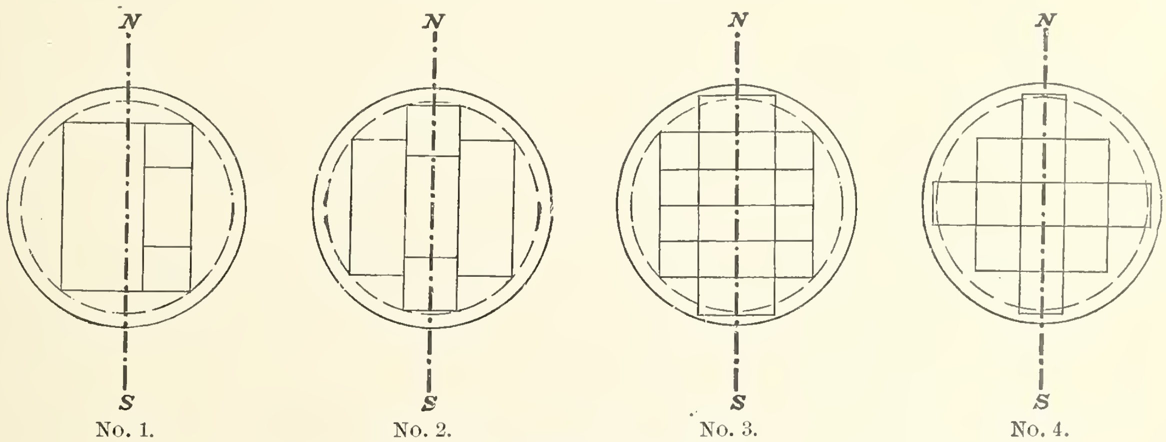


FIG. 103.—Method of sawing test logs.

EXAMINATION INTO THE PHYSICAL PROPERTIES OF TEST MATERIAL.

The physical examination consists in ascertaining the specific weight of the dried material, and incidentally the progress and amount of shrinkage due to seasoning; the counting and measuring of the annual rings, and noting other microscopic appearances in the growth; the microscopic investigation into the relation of spring and summer wood from ring to ring; the frequency and size of medullary rays; the number of cells and thickness of their walls; and, in short, the consideration of any and all elements which may elucidate the structure and may have influence upon the properties of the test piece. The rate of growth and other biological facts which may lead to the finding of relation between physical appearance, conditions of growth, and mechanical properties are also studied incidentally.

SHAPING AND MARKING OF THE MATERIAL.

The object of this work being in part the discovery of the differences that exist in the wood, not only in trees of different species or of the same species from various localities, but even in the wood of the same tree and from the same cross section, a careful marking of each piece is necessary. The disks are split, first into a north and south piece, and each of these into smaller pieces of variable size. In one tree all pieces were made but 3 cm. thick radially, in another 4 cm., in still others 5 cm., while in some trees, especially wide-ringed oaks, the pieces were left still larger. In the conifers the outer or first piece was made to contain only sapwood. Desirable as it appeared to have each piece contain a certain number of rings, and thus to represent a fixed period of growth, it proved impracticable, at least in the very narrow-ringed disks of the pines, where sometimes the width of a ring is less than 5 mm. (0.2 inch).

Some of the disks were split to a wedge shape from center to periphery, so that each smaller piece not only represents a certain period of growth in quality, but also in quantity, thus simplifying the calculations for the entire piece or disk. Other pieces were left in their prismatic form, when to calculate the average density of the entire piece the density of each smaller piece is multiplied by the mean distance of this smaller piece from the center, and the sum of the products divided by the sum of the distances.

Each piece is marked, first by the number of the tree, in Arabic; second, by the number of the disk, in Roman numbers; and if split into small pieces, each smaller piece by a letter of the alphabet, the piece at the periphery in all cases bearing the letter *a*. Besides the number and letters mentioned, each piece bears either the letter N or S, to indicate its orientation on the north or south side of the tree. To illustrate: 5—VII N *a* means that the piece bearing the label belongs to tree 5 and disk VII comes from the north side of the tree, and is the peripheral part of this disk piece. From the collector's notes the exact position of this piece in the tree can readily be ascertained.

The entire prisms sent by freight are left in the original form, unless used for special purposes, and are stored in a dry room for future use.

WEIGHING AND MEASURING.

The weighing is done on an apothecary's balance, readily sensitive to 0.1 gram with a load of more than 200 grams. Dealing with pieces of 200 to 1,000 grams in weight, the accuracy of weighing is always within 1 gram.

The measuring is done by immersion in an instrument illustrated in the following design: *V* is a vessel of iron; *S* represents one of two iron standards attached to the vessel and projecting

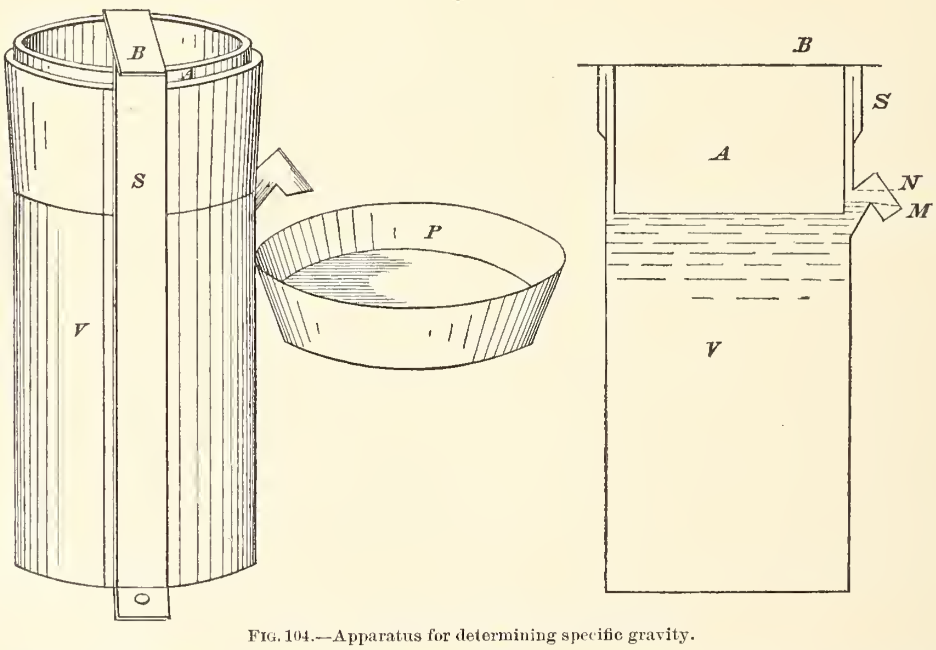


FIG. 104.—Apparatus for determining specific gravity.

above its top; *B* is a metal bar fastened to the cup *A*, which serves as guard to the cup and prevents it going down farther at one time than another by coming to rest on the standards *S*. The cup *A* dips down one-sixteenth to one-eighth of an inch below the edge of the knee-like spout. In working, the cup is lifted out by the handle which the bar *B* forms, water is poured into the vessel until it overflows through the spout, then the cup is set down, replacing the mobile and fickle natural water level by a constant artificial one. Now the instrument is set, the pan *P* is placed under the spout, the cup is lifted out and held over the vessel, so that the drippings fall back into the latter, the piece of wood to be measured is put into the vessel and the cup replaced, and pressed down until the bar *B* rests on the standards *S*. This is done gently to prevent the water from rising above the rim of the vessel. This latter precaution is superfluous where the cup fits closely, as it

does in one of the instruments thus far used. The pan with water is then weighed, the pan itself being tared by a bag of shot. The water is poured out, the pan wiped dry, and the process begins anew. To work well it takes two persons, one to weigh and record. The water pan is a seamless tin pan, holding about 1,500 cc. of water and weighing only 144 grams. The temperature as well as density of the water are ascertained, the latter, of course, omitted when distilled water is used. To maintain the water at the same temperature it requires frequent changing.

DRYING.

After marking, the pieces are left to dry at ordinary temperature. Then they are placed in a dry kiln and dried at 100° C.

The drying box used is a double-walled sheet-iron case, lined with asbestus paper, and heated with gasoline. The air enters below and has two outlets on top. The temperature is indicated by a thermometer and maintained fairly constant.

After being dried, the pieces of wood are weighed and measured, in the same way as described for the fresh wood, and from the data thus gathered the density, shrinkage, and moisture per cent are derived in the usual manner.

The formulæ employed are:

$$(1)\ \text{Density of fresh wood} = \frac{\text{Weight of fresh wood.}}{\text{Volume of fresh wood.}}$$

$$(2)\ \text{Density of dry wood} = \frac{\text{Weight of dry wood.}}{\text{Volume of dry wood.}}$$

$$(3)\ \text{Shrinkage} = \frac{\text{Fresh volume—dry volume.}}{\text{Fresh volume.}}$$

$$(4)\ \text{Moisture in wood} = \frac{\text{Fresh weight—dry weight.}}{\text{Fresh weight.}}$$

In presenting these values they are always multiplied by 100, so that the density expresses the weight of 100 $cm.^3$ of wood; thus the shrinkage and the amount of moisture become the shrinkage and moisture per cent.

SHRINKAGE EXPERIMENTS.

To discover more fully the relations of weight, humidity, and shrinkage, as well as "checking" or cracking of the wood, a number of separate experiments were made. A number of the fresh specimens were weighed and measured at variable intervals until perfectly dry. Some dry pieces were placed in water and kept immersed until the maximum volume was attained. Without describing more in detail these tests and their results, it may be mentioned that in the immersed pieces studied the final maximum volume differed very little, in some cases not at all, from the original volume of the wood when fresh; and also that in a piece of white pine only 15 cm. long and weighing but 97 gs. when dry, it required a week before the swelling ceased.

To determine the shrinkage in different directions a number of measurements are made in pieces of various sizes and shapes. In most cases pins were driven into the wood to furnish a firm metal point of contact for the caliper. A number of pieces of oak were cut in various ways to study the effect of size, form, and relative position of the grain on checking.

WOOD STRUCTURE.

The most time-robbing, but also the most fascinating, part of the work consists in the study of the wood as an important tissue of a living organism; a tissue where all favorable and unfavorable changes experienced by the tree during its long lifetime find a permanent record.

GENERAL APPEARANCE.

For this study all the specimens from one tree are brought together and arranged in the same order in which they occurred in the tree. This furnishes a general view of the appearance of the stem; any striking peculiarities, such as great eccentricity of growth, unusual color, abundance of resin in any part of the stem, are seen at a glance and are noted down.

A table is prepared with separate columns, indicating—

(1) Height of the disk in the tree (this being furnished by the collector's notes);

(2) Radius of the section;

(3) Number of rings from periphery to center;
(4) Number of rings in the sapwood;
(5) Width of the sapwood; and
(6) Remarks on color, grain, etc.

The results from each disk occupy two lines, one for the pieces from the north side and one for those of the south side. The radius is measured correct to one-half millimeter (0.02 inch), and the figures refer to the air-dry wood.

To count the rings, the piece is smoothed with a sharp knife or plane, the cut being made oblique, i. e., not quite across the grain, nor yet longitudinal. Beginning at the periphery, each ring is marked with a dot of ink, and each tenth one with a line to distinguish it from the rest. After counting, the rings are measured in groups of ten, twenty, thirty, rarely more, and these measurements entered in separate subcolumns. In this way the rate of growth of the last ten, twenty, or thirty years throughout the tree is found, also that of similar periods previous to the last; in short, a fairly complete history of the rate of growth of the tree from the time when it had reached the height of the stump to the day when felled is thus obtained. Not only do these rings furnish information concerning the growth in thickness, but indicating the age of the tree when it had grown to the height, from which the second, third, etc., disks were taken, the rate of growth in height, as well as that of thickness, is determined, any unfavorable season of growth or any series of such seasons are found faithfully recorded in these rings, and the influence of such seasons, whatever their cause, both on the quantity and on the quality or properties of the wood, can thus be ascertained.

In many cases, especially in the specimens from the longleaf pine, and from the limbs of all pines, the study of these rings is somewhat difficult. Zones of a centimeter and more exist where the width of the rings is such that the magnifier has to be used to distinguish them. In some cases this difficulty is increased by the fact that the last cells of one year's growth differ from the first cells of the next year's ring only in form and not in the thickness of their walls, and therefore produce the same color effect. Such cases frequently occur in the wood of the upper half of the disks from limbs (the limb supported horizontally and in its natural position), and often the magnifier has to be reenforced by the microscope to furnish the desired information. For this purpose the wood is treated as in all microscopic work, being first soaked in water and then sectioned with a sharp knife or razor and examined on the usual slide in water or glycerin.

The reason for beginning the counting of rings at the periphery is the same which suggested the marking of all peripheral pieces by the letter *a*. It is convenient, almost essential, to have, for instance, the thirty-fifth ring in Section II represent the same year's growth as the thirty-fifth ring in Section X. The width of the sapwood, the number of annual rings composing it, as well as the clearness and uniformity of the line separating the sapwood from the heartwood, are carefully recorded. In the columns of "remarks" any peculiarities which distinguish the particular piece of wood, such as defects of any kind, the presence of knots, abundance of resin, nature of the grain, etc., are set down.

When finished, a variable number, commonly 3 to 6 small pieces, fairly representing the wood of the tree, are split off, marked with the numbers of their respective disks, and set aside for the microscopic study, which is to tell us of the cell itself, the very element of structure, and of its share in all the properties of wood.

The small pieces are soaked in water, cut with a sharp knife or razor, and examined in water, glycerin, or chloriodide of zinc. The relative amount of the thick-walled, dark-colored bands of summer wood, the resin ducts, the dimensions of the common tracheids and their walls, both in spring and summer wood, the medullary rays, their distribution and their elements, are the principal subjects in dealing with coniferous woods; the quantitative distribution of tissues, or how much space is occupied by the thick-walled bast, how much by vessels, how much by thin-walled, pitted tracheids and parenchyma, and how much by the medullary rays; what is the relative value of each as a strength-giving element; what is the space occupied by the lumina, what by the cell walls in each of these tissues—these are among the important points in the study of the oaks.

Continued sections from center to periphery, magnified 25 diameters, are employed in finding the relative amount of the summer wood; the limits of the entire ring and that of spring and

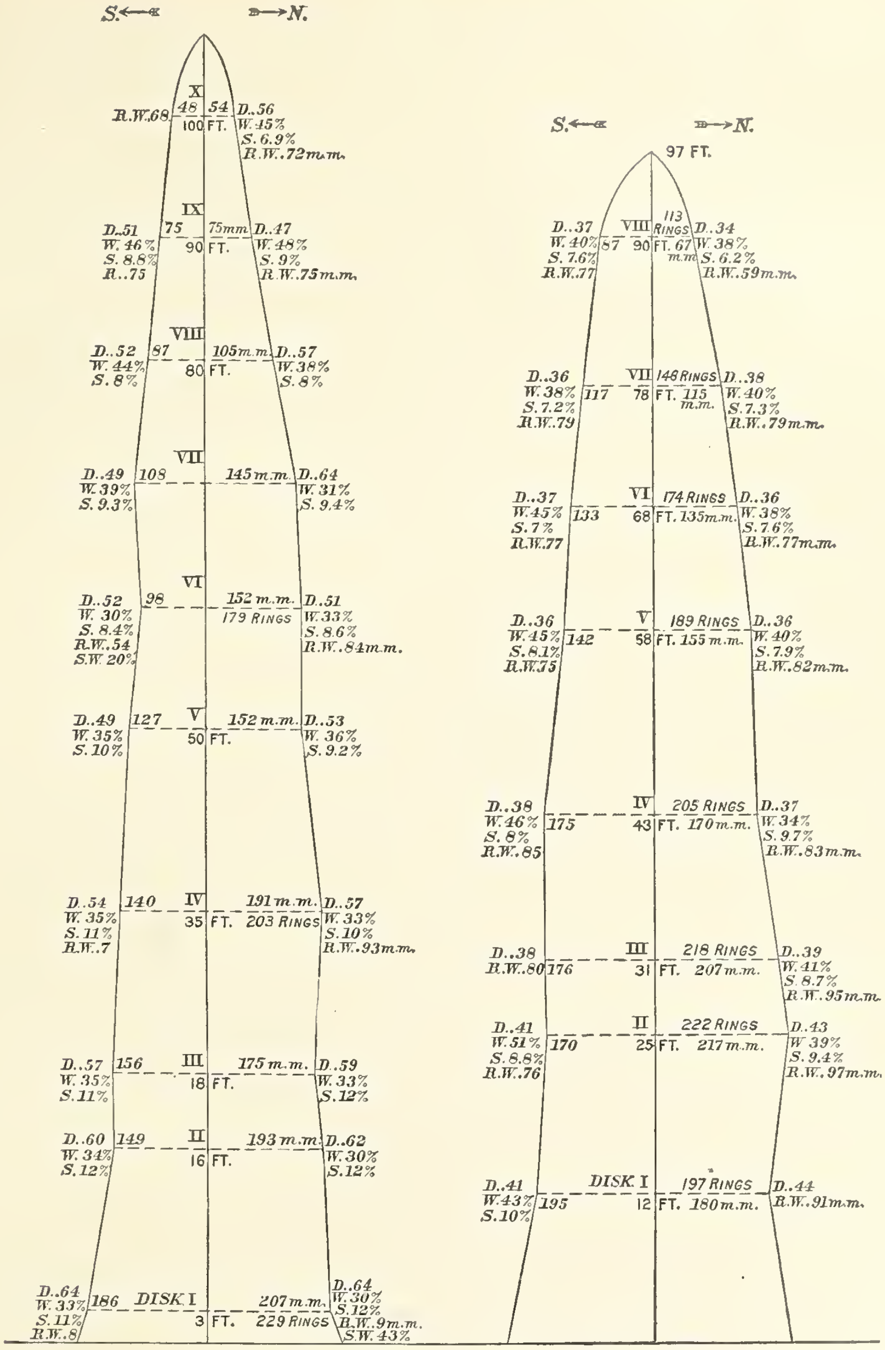


FIG. 105.—Result of physical examination. (Sample.)

LONGLEAF PINE (*P. palustris*), *tree 3.*
Locality: Wallace, Ala.
Site: Upland forest, quite dense.
Soil: Sandy.

WHITE PINE (*P. Strobus*), *tree 116.*
Locality: Marathon County, Wis.
Site: Grown in dense mixed forest.
Soil: Sandy, with sandy subsoil.

Legend.

D. Denotes density or specific gravity of the dry wood.
W. Denotes percentage of water in the fresh wood, related to its weight.
S. Denotes percentage of shrinkage in kiln drying.
R. W. Denotes width of ring (average) in millimeters (25 mm. = 1 inch).
S. W. Denotes percentage of summer wood as related to total wood.
Roman numbers refer to number of disk, placed in position of disk.

Height is given in feet from the ground; scale, 10 feet = 2 inches.
Radius, north and south (dotted line), in millimeters; scale, 10 mm. = 0.1 inch.
Median line represents the pith.
Right-hand numbers relate to north side, left-hand numbers to south side.
Outer lines represent outlines of trees.

summer wood are marked on paper with the aid of the camera, and thus a panorama of the entire section is brought before the eye. The histology of the wood, the resin ducts, the tracheids and medullary rays, their form and dimensions, are studied in thin sections magnified 580 diameters and even more. Any peculiarity in form or arrangement is drawn with the camera and thus graphically recorded; the dimensions are measured in the manner described for the measurement of the summer wood, or with the ocular micrometer. In measuring cell walls the entire distance between two neighboring lumina is taken as a "double wall," the thickness of the wall of either of the two cells being one-half of this. The advantage of this way of measuring is apparent, since the two points to be marked are in all cases perfectly clear and no arbitrary positions involved. The length of the cells is found in the usual way by separating the elements with Schultze's solution (nitric acid, chlorate of potassium). All results tabulated are averages of not less than ten, often of more than one hundred, measurements.

In the attempt to find the quantitative relations of the different tissues, as well as the density of each tissue, various ways have been followed. In some cases drawings of magnified sections were made on good, even paper, the different parts cut out, and the paper weighed. In other cases numerous measurements and computations were resorted to. Though none of the results of these attempts can be regarded as perfectly reliable, they have done much to point out the relative importance of different constituents of the wood structure, and also the possibility and practicability, and even the necessity, of this line of investigation.

INSTRUCTIONS AND BLANK FORMS, WITH ILLUSTRATIVE RECORDS.

Instructions for the Collection of Test Pieces of Pines for Timber Investigations.

A.—OBJECT OF WORK.

The collector should understand that the ultimate object of these investigations is, if possible, to establish the relation of quality of timber to the conditions under which it is grown. To accomplish this object he is expected to furnish a very careful description of the conditions under which the test trees have grown, from which test pieces are taken. Care in ascertaining these and minuteness and accuracy of description are all-important in assuring proper results. It is also necessary to select and prepare the test pieces exactly as described and to make the records perfect as nearly as possible, since the history of the material is of as much importance as the determination in the laboratory.

B.—LOCALITIES FOR COLLECTING.

As to the locality from which test trees are to be taken, a distinction is made into station and site.

By station is to be understood a section of country (or any places within that section) which is characterized in a general way by similar climatic conditions and geological formation. "Station," then, refers to the general geographical situation. "Site" refers to the local conditions and surroundings within the station from which test trees are selected.

For example, the drift deposits of the Gulf Coast plain may be taken for one station; the limestone country of northern Alabama for a second. But a limestone formation in West Virginia, which differs climatically, would necessitate another station. Within the first station a rich, moist hummock may furnish one site, a sandy piece of upland another, and a wet savannah a third. Within the second or third station a valley might furnish one site, the top of a hill another, a different exposure may call for a third, a drift-capped ledge with deeper soil may warrant the selection of another.

Choice of stations.—For each species a special selection of stations from which test pieces are to be collected is necessary. These will be determined, in each case separately as to number and location, from this office. It is proposed to cover the field of geographical distribution of a given species in such a manner as to take in stations of climatic difference and different geological horizon, neglecting, however, for the present, stations from extreme limits of distribution. Another factor which will determine choice is character of soil, as dependent upon geological formations. Stations which promise a variety of sites will be preferably chosen.

Choice of site.—Such sites will be chosen at each station as are usually occupied by the species at any one of the stations. If unusual sites are found occupied by the species at any one of the stations it will be determined by special correspondence whether test pieces are to be collected from it. The determination of the number of sites at each station must be left to the judgment of the collector after inspection of the localities; but before determining the number of sites the reasons for their selection must be reported to this office. The sites are characterized and selected by differences of elevation, exposure, soil conditions, and forest conditions. The difference of elevation which may distinguish a site is provisionally set at 500 feet; that is, with elevation as the criterion for choice of stations the difference must be at least 500 feet. Where differences of exposure occur a site should be chosen on each of the exposures present, keeping as much as possible at the same elevation and under other similar conditions. Soil conditions may vary in a number of directions, in mineral composition, physical properties, depth, and nature of the subsoil. For the present, only extreme differences in depth or in moisture conditions (drainage) and decided difference in mineral composition will be considered in making selection of sites.

Forest conditions refer, in the first place, to mixed or pure forest, open or close stand, and should be chosen as near as possible to the normal character prevailing in the region. If what, in the judgment of the collector, constitutes normal conditions are not found, the history of the forest and the points wherein it differs from normal conditions must be specially noted.

C.—CHOICE OF TREES.

On each site five trees are to be taken, one of which is to serve as "check tree." None of these trees are to be taken from the roadside or open field, nor from the outskirts, but all from the interior of the forest. They are to be representative average trees—neither the largest or best nor the smallest or worst, preferably old trees and such as are not overtopped by neighbors.

The "check tree," however, should be selected with special care, and should represent the best-developed tree that can be found, judged by relative height and diameter development and perfect crown.

The distance between the selected trees is to be not less than 100 feet or thereabout, yet care must be exercised that all are found under precisely the same conditions for which the site was chosen.

There are also to be taken six young trees as prescribed under E.

If to be had within the station, select two trees from 30 to 60 years old or older, which are known to have grown up in the open, and two trees which are known to have grown up in the forest, but have been isolated for a known time of ten to twenty years.

D.—PROCEDURE AND OUTFIT.

The station determined upon, the collector will proceed to examine it for the selection of sites. After having selected the sites, he will at once communicate the selection, with description and justification, to this office, negotiate with the owners of the timber (which might be done conditionally during the first examination) for the purchase or donation of test trees; and the latter arrangements completed, without waiting reply from this office, he will at once proceed to collect test pieces on one of the sites in regard to the selection of which he is not in doubt.

To properly carry out the instructions, the following assistants and outfit may be required:

(1) Two men[1] with ax and saw; a boy also may be of use.

(2) Team, wagon, and log trucks for moving test pieces and logs to station.

(3) Frow or sharp hacking knife for splitting disks. Heavy mallet or medium-sized "maul" to be used with frow.

(4) A handsaw.

(5) Red chalk for marking. (A special marking hammer will be substituted.)

(6) Tape line and 2-foot rule or calipers.

(7) Tags (specially furnished).

(8) Tacks (12-ounce) to fasten tags.

(9) Wrapping paper and twine.

(10) Franks for mailing test pieces (specially furnished).

(11) Shipping tags for logs.

(12) Scales, with weight power not less than 30 pounds.

(13) Barometer for ascertaining elevations.

(14) Compass to ascertain exposures.

(15) Spade and pick to ascertain soil conditions.

(16) Bags for shipping disks.

E.—METHOD OF MAKING TEST PIECES.

(a) *Mature trees.*

(1) Before felling the tree, blaze and mark the north side.

(2) Fell tree with the saw as near the ground as practicable, avoiding the flare of the butt and making the usual kerf with the ax opposite to the saw, if possible, so as to avoid north and south side. If necessary, square off the butt end.

(3) Before cutting off the butt log mark the north side on the second, third, and further log lengths.

(4) Measure off and cut logs of merchantable length and diameters, beginning from the butt, noting the length and diameters in the record.

Should knots or other imperfections, externally visible, occur within 8 inches of the log mark, make the cut lower down or higher up to avoid the imperfection.

(5) Continue measuring the full length of the tree and record its length. Note also distance from the ground and position on the tree (whether to the north, south, west, east) of one large sound limb. Mark its lower side and saw it off close to the trunk and measure its length and record it, the limb to be utilized as described later.

If the tree after felling prove unsound at the butt, it will be permissible to cut off as much or as little as necessary within the first log length. If sound timber is not found in the first log, the tree must be discarded. Only sound timber must be shipped. Any logs showing imperfections may be shortened. Be careful to note change in position of test pieces.

(6) Mark butt end of each log with a large N on north side. Saw off squarely from the bottom end of each log a disk 6 inches long, and beyond the log measure cut off disks every 10 feet up to 2-inch diameter. Place each disk

[1] Only men familiar with felling and cutting timber should be chosen.

on its bottom end, and after having ascertained and marked the north and south line on top end. Split the disk with a sharp hacking knife and mallet along this line. Split from outside of the west half of the disk enough wood to leave a prism 4 inches thick. Split from the east half two wedges with one plane in the south-north line and with their wedge line through the heart of the disk; the outer arc to be about 4 inches.

Mark each piece as split off on top side with number of the tree (Arabic), the serial number (Roman) of the disk in the tree, beginning with No. 1 at butt log, and with a distinct N or S, the north or south position of the piece as in the tree.

Write the same data on a card and tack it to the piece to which they belong. Whenever disk pieces are small enough for mailing, leavé them entire. Whenever they can not be shipped by mail, leave disks entire, wrap in paper, and ship by express.

(7) Weigh each piece and record weight in notebook, using the same marks as appear on the pieces.

(8) Wrap each piece in two sheets of heavy wrapping paper and tie securely.

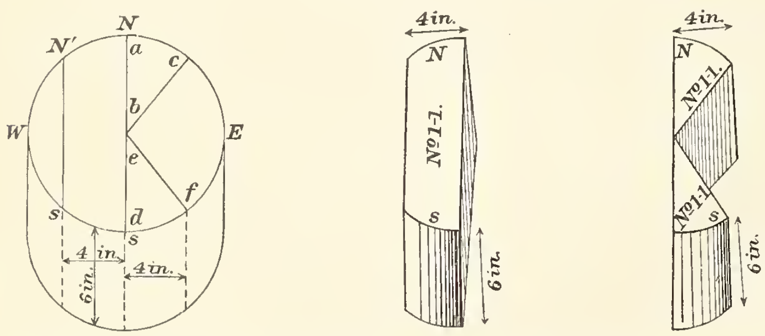
(9) Mark on the newly cut bottom end of each log with a heavy pencil a north and south line, writing N on the north and S on the south side of the log, large and distinct. Also mark centrally with an Arabic number on each log the number of the tree in the series, and with a distinct Roman number the serial number of the log in the tree, counting the butt log as first.

Tack to the butt end of each log securely a card (centrally), on which is written name of tree, species, locality from which tree is taken, denoted by the letter corresponding to that used in the notebook, number of tree, and section. This card or tag is intended to insure a record of each log in addition to the marking already made.

(10) *Limb wood.*—Having, as before noted, selected a limb, measured and recorded its distance from the butt and position on the trunk, and marked its lower side and sawed it off close to the latter, now take a disk 6 inches long from the butt end and others every 5 feet up to 2-inch diameter at the top. Number these consecutively with Roman number, calling the butt disk No. 1. Note by letters L and U the lower and upper side, as the limb appeared on the tree, and place the (Arabic) number of tree from which the limb came on each. Enforce the record by cards containing the same information, as done in case of other disk pieces.

Weigh and wrap and mail in the same manner as the other pieces.

(11) *Check trees.*—From the "check tree," which is to be the very best to be found, only three disks or three logs are to be secured, from the butt, middle, and top part of the tree Absolutely clear timber, free from all knots and blemishes, is to be chosen. The disk pieces are to be of the same size, and to be secured in the same manner as those described before; the logs to be not necessarily more than 6 feet; less if not enough clear timber can be found.



Note the position of each piece in the tree by measuring from the butt cut to the butt end of the piece.

Prepare and mark all pieces in the same manner as those from other trees, adding, however, to each piece a × mark to denote it as coming from the "check tree."

(12) *Young trees.*—Select six trees from each site approximately of following sizes: Two, 6-inch diameter, breast high; two, 4-inch diameter, breast high; two, 2-inch diameter, breast high. Mark north and south sides and chop or saw all close to the ground and cut each tree into following lengths: First stick, 2 feet long; second stick, 4 feet long; the remaining cuts 4 feet long up to a top end diameter of about 1 inch. Cut from the basal end of each log a disk 6 inches long. Mark and ticket butt end of each log as in case of large trees. Mark a north and south line on *top* end of each disk, with N and S at extremities to denote north and south sides; and also ticket with same data as given on large disk pieces. Weigh and wrap as before. Of these trees only the disk pieces are to be mailed.

F.—SHIPPING TEST PIECES.

Ship all pieces without delay. To each log tack securely a shipping card (furnished), so as to cover the marking tag. The logs will go to J. B. Johnson, St. Louis, Mo. The disks and other pieces are to be mailed to F. Roth, Ann Arbor, Mich., using franks, securely pasted, for mailing, unless, as noted before, they must be sent by express.

Mail at once to the above addresses notice of each shipment, and a transcript of notes and full description to this office, from which copies will be forwarded to the recipients of the test pieces.

If free transportation is obtained from the railroad companies, special additional instructions will be given under this head.

G.—RECORDS.

Careful and accurate records are most essential to secure the success of this work. A set of specially prepared record sheets will be furnished, with instructions for their use. A transcript of the record must be sent to this office at the time of making shipment; also such notes as may seem desirable to complete the record and to give additional explanations in regard to the record and suggestions respecting the work of collecting. Original records and notes must be preserved, to avoid loss in transmission by mail.

FORM OF FIELD RECORD.

(Folder.)

Name of collector: (Charles Mohr.) Species: Pinus palustris.

STATION (denoted by capital letter): A.

State: Alabama. County: Escambia. Town: Wallace.

Longitude: 86° 12′. Latitude: 31° 15′. Average altitude: 75 to 100 feet.

General configuration: Plain—hills—plateau—mountainous. General trend of valleys or hills ....

Climatic features: Subtropical; mean annual temperature, 65°; mean annual rainfall, 62 inches.

SITE (denoted by small letter): a.

Aspect: Level—ravine—cove—bench—slope (angle approximately).

Exposure: .... Elevation (above average station altitude): 125 feet.

Soil conditions:

(1) Geological formation (if known): Southern stratified drift.

(2) Mineral composition: Clay—limestone—loam—marl—sandy loam—loamy sand—sand.

(3) Surface cover: Bare—grassy—mossy. Leaf cover: Abundant—scanty—lacking.

(4) Depth of vegetable mold (humus): Absent—moderate—plenty—or give depth in inches.

(5) Grain, consistency, and admixtures: Very fine—fine—medium—coarse—porous—light—loose—moderately loose—compact—binding—stones or rock, size of ....

(6) Moisture conditions: Wet—moist—fresh—dry—arid—well drained—liable to overflow—swampy—near stream or spring or other kind of water supply ....

(7) Color: Ashy-gray.

(8) Depth to subsoil (if known): Shallow, 3 to 4 inches to 1 foot—1 foot to 4 feet, deep—over 4 feet, very deep—shifting.

(9) Nature of subsoil (if ascertainable): Red, ferruginous sandy loam; moderately loose, or rather slightly binding; always of some degree of dampness; of great depth.

Forest conditions: Mixed timber—pure—dense growth—moderately dense to open ....

Associated species: None.

Proportions of these ....

Average height: 90 feet.

Undergrowth: Scanty; in the original forest often none.

Conditions in the open: Field—pasture—lawn—clearing (how long cleared): In natural clearings untouched by fire, dense groves of second growth of the species.

Nature of soil cover (if any): Weeds—brush—sod.

(Inside of folder.)

STATION: A. SITE: a. SPECIES: P. palustris. TREE NO. 3.

POSITION of tree (if any special point notable not appearing in general description of site, exceptional exposure to light or dense position, etc., protected by buildings, note on back of sheet): In rather dense position.
ORIGIN of tree (if ascertainable): Natural seedling, sprout from stump, artificial planting.

DIAMETER breast high: 16 inches.
HEIGHT to first limb: 53 feet.
AGE (annual rings on stump): 183.

HEIGHT of stump: 20 inches.
LENGTH of felled tree: 110 feet 4 inches.
TOTAL height: 111 feet 8 inches.

No. of disk.	Distance from butt.	Weight of combined disk pieces.	Remarks.	No. of log.	Distance from butt.	Length of log.	Diameter, butt end.
	Feet.	Pounds.			Ft. In.	Ft. In.	Inches.
I	0	27	Crown touching those of nearest trees to the N. and NE. Open toward SW.	I	8 0	12 4	$16\frac{3}{4}$
II	13	20		II	13 8	5 4	$14\frac{1}{2}$
III	19	20		III	19 8	12 4	14
IV	32	18		IV	32 8	14 4	$13\frac{1}{2}$
V	47	16		V	47 8	9 4	$12\frac{1}{4}$
VI	57	14		VI	57 8	9 4	$11\frac{1}{8}$
VII	67	17		VII	67 8	9 4	$9\frac{3}{4}$
VIII	77	14		VIII	77 8	9 4	$8\frac{1}{2}$
IX	87	$9\frac{1}{2}$					
X	97	6					

LIMBWOOD:
DISTANCE from butt: POSITION on trunk: TOTAL length:
NUMBER of disks taken:

NOTE.—As much as possible make description by underscoring terms used above. Add other descriptive terms if necessary.

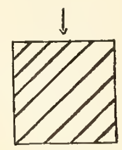
SAMPLE RECORDS OF TESTS.

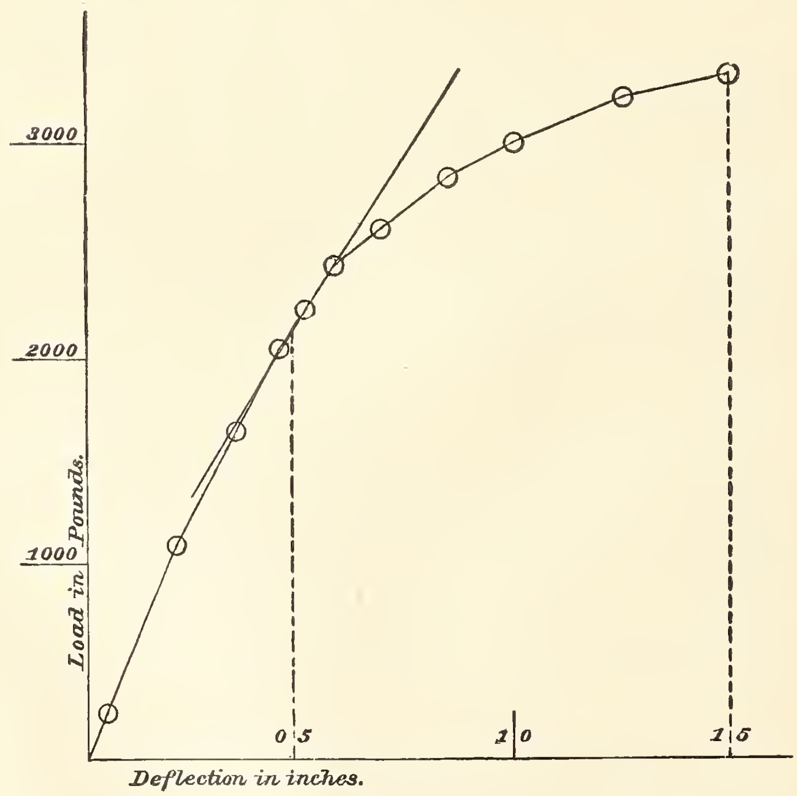
CROSS BREAKING TEST.

Mark, {116. 1. 3.} White pine.
Length, 60.0 inches.
Height, 3.74 inches.
Breadth, 3.75 inches.

Strength of extreme fiber,
where $f=\frac{3\ W\ l}{2\ b\ h^2}$=5,660 pounds per square inch.
Modulus of elasticity =1,320,000 pounds per square inch.
Total resilience =3,460 inch-pounds. El. Res., 550.
Resilience, per cubic inch =4.11 inch-pounds. El. Res., 0.65.

[Number annual rings per inch =19.]

July 18, 1891.	Load.	Deflection.	Micrometer.	Remarks.
h. m.				
4 24	.200	.042	0.757	
25	1,000	.211	0.926	
26	1,600	.300	1.065	
27	2,000	.454	1.169	
28	2,200	.511	1.226	
29	2,400	.595	1.310	
31	2,600	.690	1.405	
33	2,800	.853	1.568	
35	3,000	1.015	1.730	N
37	3,200	1.276	1.991	
40	3,300	1.521	2.236	Maximum load.



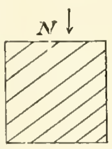
CROSS BREAKING TEST.

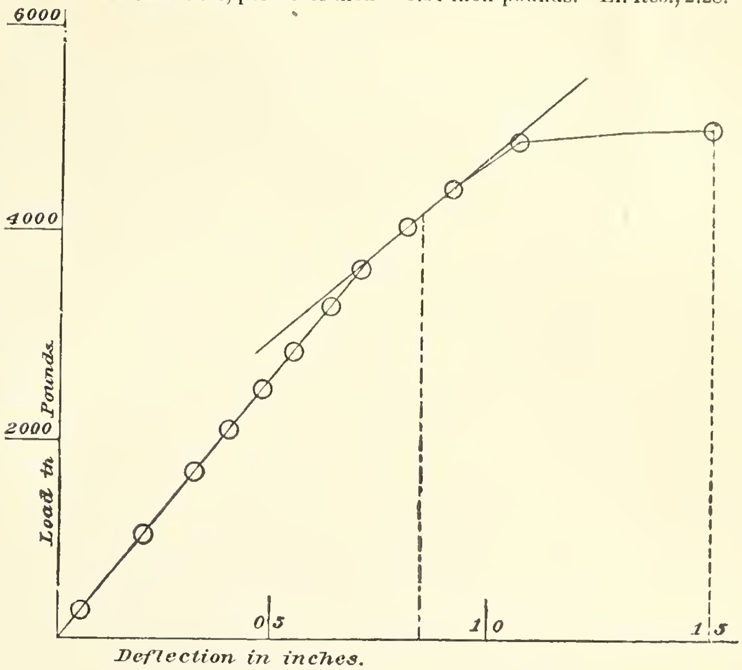
Mark, {3. 3. 1. Longleaf pine.
Length, 60.0 inches.
Height, 3.50 inches.
Breadth, 3.72 inches.

Strength of extreme fiber,
where $f=\frac{3}{2}\frac{W\,l}{b\,h^2}$=10,230 pounds per square inch.
Modulus of elasticity =1,760,000 pounds per square inch.
Total resilience =5,110 inch-pounds. El. Res., 1,780.
Resilience, per cubic inch =6.54 inch-pounds. El. Res., 2.28.

[Number annual rings per inch=23.]

July 20, 1891.	Load.	Deflection.	Micrometer.	Remarks.
h. m.				
2 58	200	.042	0.958	
3 0	1,000	.208	1.124	
1	1,600	.324	1.240	
2	2,000	.404	1.320	
3	2,400	.481	1.397	
4	2,800	.558	1.474	
5	3,200	.640	1.556	
6	3,600	.721	1.637	
7	4,000	.815	1.731	
8	4,400	.926	1.842	
9	4,800	1.074	1.990	
13	5,180	1.544	2.460	Maximum load





FINAL RECORD OF TIMBER TESTS.

Mark.	Percentage of moisture.	Cross bending test. Dimensions. Length.	Height.	Breadth.	Time.	Load.	Deflection.	Strength per square inch. (*f*)	Modulus of elasticity. (*e*)	Resilience in inch-pounds per cubic inch. (*r*)
		Inches.	*Inches.*	*Inches.*	*Min.*	*Pounds.*	*Inches.*	*Pounds.*	*Pounds.*	
Longleaf pine: 3, 3, 1	16.8	60.0	3.50	3.72	15	5,180	1,544	10,230	1,760,000	6.54
White pine: 116, 1, 3	54.3	60.0	3.74	3.75	16	3,300	1,521	5,660	1,320,000	4.11

Mark.	Crushing endwise. Dimensions. Height.	Cross section.	Area.	Crushing load.	Strength per square inch.	Crushing across grain. Dimensions. Height.	Cross section.	Area.	Crushing load.	Strength per square inch.
	Inches.	*Inches.*	*Sq. in.*	*Pounds.*	*Pounds.*	*Inches.*	*Inches.*	*Sq. inch.*	*Pounds.*	*Pounds.*
Longleaf pine: 3, 3, 1	8.1	3.46 3.72	12.87	77,700	6,040	3.73	3.47 3.93	13.63	10,400	760
White pine: 116, 1, 3	7.6	3.73 3.73	13.91	48,400	3,480	3.72	3.72 3.93	14.62	5,200	360

Mark.	Tension tests. Size of reduced section.	Area.	Breaking load.	Strength per square inch.	Shearing tests. Total shearing area.	Breaking load.	Shearing strength.
	Sq. inch.	*Sq. inch.*	*Pounds.*	*Pounds.*	*Sq. inch.*	*Pounds.*	*Pounds.*
Longleaf pine: 3, 3, 1	2.38 .41	0.976	11,400	11,680	4.14 3.97	2,280 2,580	551 650
White pine: 116, 1, 3	2.52 .45	1.134	11,200	9,880	4.16 4.02	1,700 1,600	409 398

J.—METAL TIES FOR RAILWAYS, AND ECONOMIES IN THE USE OF WOODEN TIES.

E. E. Russell Tratman, C. E.

Assoc. Mem. Am. Soc. Civ. Engs.—Mem. Am. Inst. Min. Engs.

The use of metal ties as a substitute for wooden ties in railway track has been practiced in foreign countries for many years on a very extensive scale and with great success, but though the matter has been given some attention in this country, very little has been done except in the way of a few small experiments. This is due in part to the general, though erroneous, idea that our still abundant timber resources are inexhaustible; and also to the comparatively high first cost of metal ties (the possible future economy resulting from their use being frequently overlooked). In fact the matter is, on the whole, regarded with indifference. Another reason for this is, perhaps, a tendency to question the application of foreign experience to American railways. There is, too, a wide impression that the use of metal ties in other countries is merely experimental and on a small scale, whereas in point of fact they have been extensively adopted for main lines carrying heavy traffic, as well as for lighter lines, and they have certainly long since passed the experimental stage. Nearly 35,000 miles of track are now laid with metal ties.

The writer has given the subject considerable attention for several years past, and in 1887 was requested by Mr. B. E. Fernow, then chief of the Division of Forestry, to make a special investigation and report thereon to the Division in the interests of the preservation of the timber resources of the country. Three reports have since been made, forming Bulletins No. 3, No. 4, and No. 9 of the Division of Forestry. The first, in 1889, was a preliminary report of progress. The second and third, issued in 1890 and 1894, were comprehensive reports, giving full particulars of foreign practice and discussing the entire subject. In both of these reports very full details were given of: (1) various forms of metal ties and their fastenings, as well as of the track of which they form a part; (2) the character of the rolling stock and traffic; (3) the results obtained from their use. As there was then no comprehensive work on the subject, special attention was given to describing the ties, fastenings, etc., in detail. The third report (1894) had a somewhat wider scope and included the use of metal tie-plates and preservative processes for increasing the life and efficiency of wooden ties.

On foreign railways the many improvements in shape, material, and manufacture of steel ties and their fastenings, and the careful investigation as to the work of maintenance, particularly since 1880, are now showing results in decidedly favorable estimates as to maintenance and renewals on railways where steel ties have been extensively and intelligently used. A large number of the important patents on steel ties have now expired and have no longer an influence on the cost of manufacture, so that the various systems can be considered purely on their merits. The consideration of the respective merits of metal and wooden ties is a very important matter in many European and other countries, where, owing to conditions of climate or to the relative cost of timber and steel, the use of metal ties may effect a direct financial economy as well as a general improvement in the track.

The subject is, perhaps, not of such immediate interest or importance in this country, where timber is still comparatively plentiful. The use of protective steel tie-plates has made the cheaper and inferior qualities of timber largely available for railway service, while the use of preservative

processes of chemical treatment have not yet been developed to any great extent. Nevertheless, in view of the great and steady demand for timber for railway and other purposes, and in view also of the steady reduction in the timber resources by legitimate consumption and various destructive agencies, it seems inevitable that the price of wooden ties will continue to increase. Such an increase in the price of timber, with a reduction in the price of steel, may introduce in this country conditions approximately similar to those which have led to the extensive introduction of steel ties in other countries.

The relation of this question to the forestry interests, however, is not the only one to be considered. In many instances the use of metal ties may effect a decided improvement in the track and an economy in the expenses for track maintenance. In fact there are probably many places in this country now where metal ties might be used with advantage. For these reasons therefore it may be said that it will be well for progressive railway men to begin to consider the conditions under which metal ties have been used abroad and the results of experience with these ties, with a view to the possibilities of their introduction upon American railways.

In discussions upon the metal-tie question two extreme arguments are frequently put forward. One of these is to the effect that the use of such ties is merely a fad and an unsuccessful experiment, while the other is to the effect that metal ties are essential for a safe and substantial track. The abandonment of some experiments on the Pennsylvania Railroad a few years ago was made the basis of conclusions, which were widely circulated, to the effect that metal ties as a whole were a complete failure. As a matter of fact the very limited trials on that road and the styles of ties used did not warrant any general conclusions; on the other hand, legislative action to compel the use of metal ties has even been advocated.

The introduction of good metal ties, however, is a matter of development and not of arbitrary action; of evolution rather than of revolution. It must be remembered also that while innumerable forms and modifications of metal ties have been devised only a very limited proportion of these are such as to warrant trial, while the ties which have been most extensively and successfully used comprise but a very few general types. Among the 750 patents taken out in this country and recorded in my reports very few are at all practicable or show any qualifications on the part of the inventor for designing such an article as a railway tie. The same remarks apply to the fastenings of the rails to metal ties.

The necessity for economy in the use of our timber resources is due to the fact that the consumption has for a long time been excessive as compared with reproduction, and that ties are largely obtained from young trees, thereby reducing the supplies needful for the future. Taking the low average of 2,500 ties per mile, the 240,000 miles of railway track represent 600,000,000 ties in service. The average life is but seven years, and renewals require at least 85,000,000 ties per annum, while about 7,500,000 are required for new construction. The 16,500 miles of street railway represent about 33,000,000 ties, and require about 4,000,000 per year for renewals and 2,500,000 for new construction. This gives a total annual consumption of about 100,000,000 ties, equivalent to 500,000,000 cubic feet of forest timber.

A very serious matter is that the proper consumption of timber represents but a part of the total amount of standing timber removed. The constant troubles from reckless and wasteful methods of cutting, the wholesale illegal cutting of timber on Government and private lands, and the destruction due to forest fires, sheep herding, etc., point to the necessity of protecting the timber resources and economizing in the use of timber. The treatment of these resources in other countries as a source of revenue to the government, by placing them in charge of skilled men under a government department, has been so markedly successful that I have been impelled to strongly support the movement in favor of a similar system of forest regulation and administration by the Government of the United States.

Apart from the desirability of obtaining a substitute for wooden ties, in the interests of forest preservation, there is another very important point, and one which is really of more direct importance to American railways. This is the reduction in annual renewals of ties, due to the longer life of metal ties, and this again effects a consequent reduction in labor expenses. It also results in a better and more permanent condition of the track, due to the less frequent disturbance of the ballast and roadbed. The general experience is that while the expense of maintenance of track with metal ties is at first equal to, or even greater than, that for track with wooden ties,

yet that after three or four years the cost becomes rapidly less, while for wooden ties the expense increases year by year until renewals are necessary.

As a result of the investigations, the following general conclusions may be presented:

First. Metal ties are used very extensively, and their use is being continually extended.

Second. While different results are reported, the experience is usually favorable, particularly where well designed ties have been used.

Third. The introduction of metal ties effects an appreciable economy in timber, and may lead to an important development of the iron and steel industries.

Fourth. Among the advantages of metal ties over wooden ties the following may be noted:

(*a*) Reduction in the annual consumption of timber.

(*b*) Greater length of life, with consequent saving in renewal expenses, and a general economy in track work.

(*c*) Maintaining a better and more uniform track for a longer time and with less work upon the track.

(*d*) Reduced expenses for maintenance and renewals, owing to the greater durability of the track.

(*e*) Increased safety, owing to the more efficient fastenings and the more permanent character of the ties.

In view of the durability of the track and the economy in track work which results from the use of an efficient system of metal ties, it would seem that there are already many special locations in this country where such ties might now be used with financial and practical advantage. This is particularly the case on busy main lines near large cities and terminals, where the continued traffic not only makes constant work necessary, but makes it difficult and expensive to carry on the work.

For street railway track metal ties are particularly well adapted. They are extensively used for this purpose abroad, and in this country they are used much more for such track than for steam-railway track.

The following tabular summary, which is condensed from tables given in my report of 1894, shows what an important extent of the railway's throughout the world is laid with metal ties. Such ties were then in use on 35,000 miles of track, or nearly 10 per cent of the total railway mileage, or on nearly 20 per cent, if we exclude the mileage of the United States and Canada, whose railways have but an infinitesimal percentage of metal track. At the present time the percentage is probably about the same or even somewhat higher, the use of metal ties having increased more rapidly than the construction of new railways.

Statistics of metal track.

SECTION NO. 1.—EUROPE.

	Miles.		Miles.
England	73	Sweden and Norway	[illegible]
France	128	Denmark	[illegible]
Holland	322	Russia	[illegible]
Belgium	176	Turkey (Europe)	[illegible]
Germany	11, 605	Turkey (Asia)	[illegible]
Austria and Hungary	216½	Greece	[illegible]
Bosnia	12		
Switzerland	480	Total metal track	[illegible]
Spain	264	Total track	[illegible]
Portugal	1		

SECTION NO. 2.—AFRICA.

Egypt	866	South Africa (Portuguese)	48
Algeria	164	Cape Colony	[illegible]
Abyssinia	14	East Coast	125
Sudan	2	Réunion	[illegible]
Senegal	30		
Kongo (Portuguese)	5	Total metal track	[illegible]
Kongo (Free State)	61	Total track	5, 575
South African Republic	115		

Statistics of metal track—Continued.

SECTION NO. 3.—AUSTRALASIA.

	Miles.
Queensland	82
South Australia	152
Total metal track	234
Total track (7 colonies)	12,000

SECTION NO. 4.—ASIA.

	Miles.		Miles.
British India	13,655	Japan	5
Sumatra	90	Asia Minor	309
Java	500		
Straits Settlements	25	Total metal track	14,586
China	2	Total track	22,000

SECTION NO. 5.—SOUTH AMERICA, ETC.

Argentine Republic	3,638	Mexico	220
Chile	1		
Brazil	135	Total metal track	4,416
Venezuela	218	Total track	21,500
West Indies	204		

SECTION NO. 6.—NORTH AMERICA.

United States	12
Canada	0
Total metal track	12
Total track (United States and Canada)	190,000

Percentage of metal track mileage.

	Metal track.	Total track.	Per cent of metal track.
	Miles.	*Miles.*	
Section No. 1	13,404	137,000	10
Section No. 2	2,326	5,600	40
Section No. 3	234	12,000	2
Section No. 4	14,586	22,000	66.3
Section No. 5	4,416	21,500	21
Section No. 6	12	190,000	0
Total	34,863	388,100	9

Total mileage of railways with metal track ....miles.. 34,863
Total mileage of railways of the world (exclusive of United States and Canada) ....miles.. 198,000
Percentage of railways with metal track (exclusive of United States and Canada) ....per cent.. 17.6

It is not necessary in this general review of the subject to go into the details of the practice and experience of foreign railways, as such details have been given very fully in the reports already referred to. As the latest examples of this experience, however, it will be of interest to present some particulars from reports recently made by Mr. Renson, resident engineer of the Netherlands State railways (Holland), and Mr. Schrafl, engineer of the Gotthard Railway (Switzerland). On both of these lines metal ties have been in use for several years, and have been improved upon from time to time in the light of practical experience, while very careful investigations have been made as to their efficiency and economy.

On the Netherlands State railways the first metal ties were laid in 1865, and are still in good condition. They are, in fact, expected to last from three to eight years more. In 1880, however, Mr. J. W. Post was commissioned to make an investigation of the subject. This resulted in a series of extensive and practical tests on main lines, the design of the ties being modified and improved from time to time. The first ties of this series (1881) were the lightest and least successful, but they lasted longer than good oak ties, while the annual charge for their renewal was only half that for the oak ties. The maintenance expenses were higher, but, on allowing for

the difference in the renewal charges, there was actually a balance of about $43 per mile of track per year in favor of the metal ties. With the later forms of ties the maintenance expenses were steadily reduced, and with the latest forms now in use these expenses are less than for oak ties. Rusting and wear of the bolt holes have been insignificant, and it has been found that, by inserting renewable tie plates between the rail and the tie, the life of the latter can be extended almost indefinitely. The results of the seventeen years' experience have been entirely satisfactory, and Mr. Renson closes his report with the following statement:

> I am glad to state that the result of our seventeen years' work fully confirms the favorable opinion of many engineers who have specially studied the metal-track question, particularly Messrs. Ch. Bricka, J. W. Post, A. M. Kowalski, E. E. Russell Tratman, Ch. Lebon, and Dictler. Our results quite agree also with the favorable results on some of those railways on which the question has been investigated extensively and with perseverance, by giving different systems a fair trial, uninfluenced by preconceived ideas.

On the Gotthard Railway metal ties have been in use since 1882, and the experience with them has been such as to lead the road to introduce them very extensively. They now represent 70 per cent of the ties in main track and 39 per cent of those on sidings, or 65 per cent for the entire line. The cost at the present time is $1.72 per tie, as against $1.20 for oak. If the fastenings are included, the costs are $1.96 and $1.61 respectively. Adding the cost of laying, however, and then deducting the value of the old material, the net result shows only $1.60 for the steel tie, as compared with $1.66 for the oak tie. For the first year or two the expenses for ordinary maintenance of track are about the same for both steel and wooden ties, but after that period the expenses become materially lower for the metal track.

This railway has 43 per cent of its length on curves and has grades of 2.7 per cent, while the traffic is heavy and includes express trains running at 40 to 53 miles per hour. In the numerous long tunnels the ties are subject to rust, and last only eight to ten years, which is about the same life as that of the oak ties. Elsewhere, however, the rusting and wear of the ties are so slight that the ties are expected to last as long as the rails. The general result, in point of durability, is that the steel ties have proved to be more economical than the oak ties. The report further states that even if they were less economical, the railway would still feel obliged to use the steel ties on account of the greater safety and security of the track.

One other case may be cited as an example of the common use of metal ties on foreign railways. During the years 1895–1898, about 160 miles of metal track on the Wurttemberg State railways were renewed at a reported cost of about $1,750,000, in order to provide for increased weight and amount of traffic. The old track consisted of 66-pound rails, 29 feet 6 inches long, with 10 or 12 ties per rail, the ties weighing 114 pounds each, and being spaced 30 and 36 inches center to center. The new track consists of 87-pound rails, 39 feet 4 inches long, with 16 or 17 ties per rail, the weight of the ties being 155 pounds, and the spacing 28 and 30 inches. The old track weighed 266 to 2[illegible] pounds per yard, while the new track weighs 408 to 422 pounds per yard.

This report would not be complete without some reference to means of effecting economies in the use of wooden ties, as this is a matter of immediate importance to American railways. Wooden ties will undoubtedly continue to be generally used in this country for many years to come, and it is important that railway officers should without delay give attention to the advantages of increasing the efficiency and economy of such ties by protecting them from decay and wear. The use of preservative processes to prevent decay and the use of protective metal tie plates to prevent wear and disintegration under the rails may be made to effect a marked economy in the track work by increasing the life of the ties, reducing the expense of renewals, and enabling the cheap [illegible] inferior timbers to be effectively used for ties. The ties so treated and protected also make [illegible] track and one which requires less work for maintenance.

The renewing of ties is too often considered as a comparatively unimportant item in the maintenance expenses, but in point of fact the average cost of tie renewals very frequently exceeds that of rail renewals, and the cost also has a continual tendency to increase. The cost may often be materially reduced by careful methods of checking to prevent the premature removal of comparatively sound ties and by the more general use of preservative treatment and metal tie plates. It must be remembered that a road which has to renew its ties in six years is at a great disadvantage as compared with another whose ties last twelve years. The former must [illegible]

its expense account almost double the cost for material, besides the additional track labor required to do the work, while during the interval it can not have as good a track as the latter.

Although the practical economies resulting from the use of preservative processes have been amply proved, both in this country and abroad, and although such processes are very extensively employed abroad, they have been but indifferently regarded here by railway officers, with some important exceptions. The economy results not only from the increased life of the ties and the possibility of making cheaper and inferior timber give as good service as the higher grades of timber, but also from the reduced labor and cost of maintenance and the improved surface of track due to reduction in tie renewals. Under ordinary conditions the track has hardly been got into good surface on a settled roadbed before it is disturbed again by renewing ties. In view of these facts, and of the further fact that so many important railways are now spending enormous sums of money in the improvement of their lines, it is strange that so few railways have taken up this matter on a large scale.

One of the most important and practical of modern improvements in American railway track has been the wide introduction of metal tie plates, which are placed between the rail and the tie. Their purpose is to prevent the cutting and wearing of the tie, which frequently necessitate the removal of sound ties from the track. The small cost of these plates and the undoubted advantages which they insure in economy in ties and in track work have led to their use on many hundreds of miles of track. They not only lengthen the life of the ties, but also give a better and more permanent bearing for the rails. Similar plates, but of much heavier construction and secured by bolts or spikes, have for many years been used in Europe. The special feature of the small and light American plates is that they have ribs or points which are pressed into the wood, so that the plate becomes practically a part of the tie, independent of the rail fastenings.

The greatest economy in track with wooden ties will in general be insured by protecting the ties from decay by means of a chemical treatment, and protecting them from abrasion or wear by means of the application of metal tie plates.

In conclusion, two statements may be presented, based upon the information given in my reports and upon the present review of the situation.

First. The advantages and economies resulting from the use of metal ties are such as to make it advisable to consider their application to American railways (in special cases, at least) in the near future.

Second. The advantages and economies which may be obtained by the application of tie plates and preservative processes to wooden ties are so great that the use of such methods should be considered as a matter of immediate importance.

Ha[illegible]